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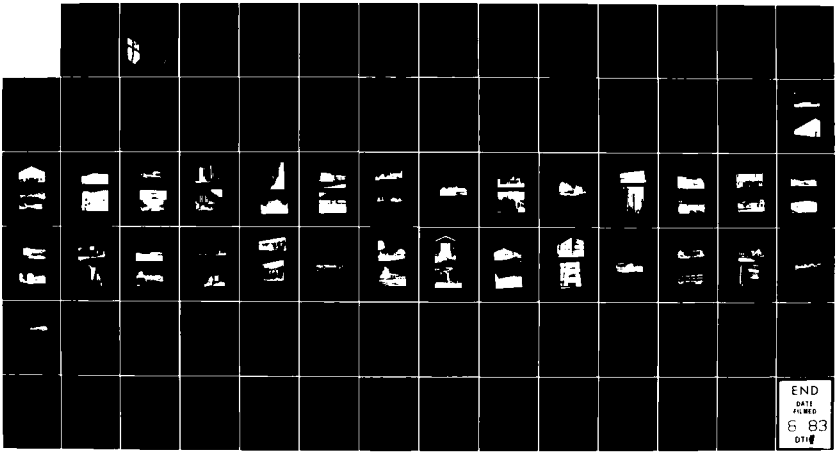

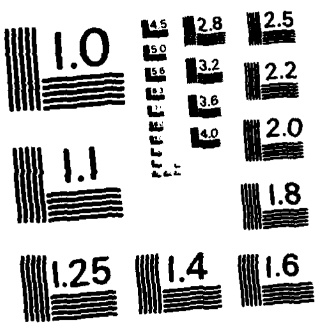

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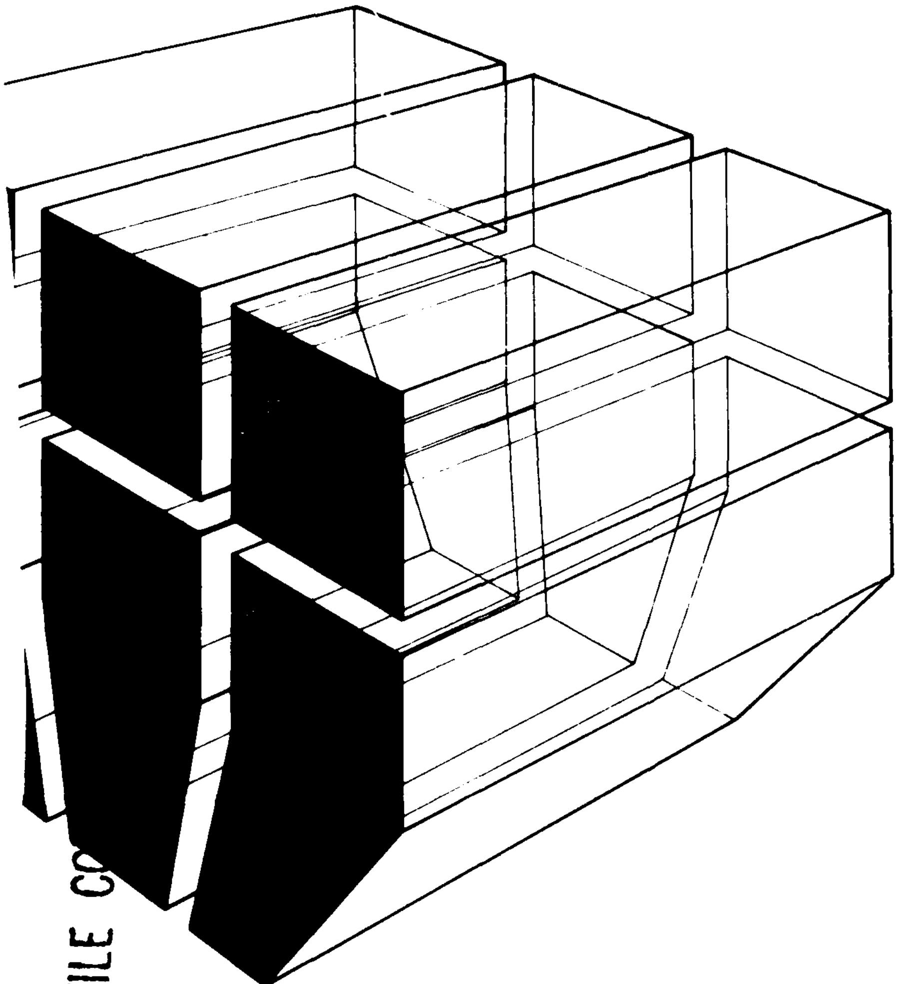
Technical Report M-327
March 1983

PRELIMINARY ANALYSIS OF THE SEISMIC VULNERABILITY OF SELECTED BUILDINGS AT FORT ORD, CALIFORNIA, USING THE RAPID SEISMIC ANALYSIS PROCEDURE



by
T. K. Lew

CERL

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A preliminary evaluation of the seismic vulnerability of a selected group of 17 essential and high-potential-loss buildings at Fort Ord, CA, was conducted using the Navy's Rapid Seismic Analysis (RSA) procedure. This procedure estimates the potential earthquake ground-shaking effects on buildings, including estimated damage and the cost of these damages. In addition, a list of recommended modifications to enhance the accuracy and capabilities of the RSA procedure was also developed. Where appropriate, these modifications were incorporated into the analysis of the selected group of buildings. Based on the

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results of the preliminary evaluation, about one third of the buildings in the initial group would have estimated damage greater than 60 percent of their estimated replacement cost under the maximum site ground acceleration of 0.40 g. This indicates that the buildings analyzed have a high probability of being severely damaged or of collapsing under the maximum site ground acceleration. It was recommended that these buildings be analyzed in detail to determine the degree of strengthening and cost required to reduce the seismic hazards to these buildings and their occupants.

FOREWORD

This study was performed by the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, CA, for the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (CERL). The work was performed under MIPR-CIAO 81-58 in support of the Directorate of Engineering and Construction, Office of the Chief of Engineers (OCE), RDT&E Program 6.27.12A, Project 4A762731AT41, "Military Facilities Engineering Technology"; Technical Area A, "Facility Planning and Design"; Work Unit 037, "Hazard Indexing/Prioritizing System (HIPS) for Military Buildings."

Mr. B. Haumen, Mr. C. Canlas, Ms. B. Rees, Ms. J. Stevens, and other members of the Facility Engineer staff at Fort Ord provided NCEL with the architectural and structural drawings and other information used in ths study. Mr. K. Mack (NCEL) extracted data from the structural drawings and computed the building properties used in the analysis. The section on strengthening costs and Table 10 were written by CERL personnel. Dr. James D. Prendergast was the CERL project monitor for this investigation. Mr. G. Matsumura, DAEN-ECE-T, was the OCE Technical Monitor. Dr. R. Quattrone is Chief of EM.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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PRELIMINARY ANALYSIS OF THE *SEISMIC* VULNERABILITY OF SELECTED BUILDINGS AT FORT ORD, CALIFORNIA, USING THE RAPID SEISMIC ANALYSIS PROCEDURE

1 INTRODUCTION

Background

Most of the permanent structures at military installations have been constructed according to the seismic codes applicable during their design. These codes are intended to give the buildings some protection from seismic hazards. However, as more earthquake data became available, it was necessary to increase the design force levels in the older codes, and to change certain design details to improve seismic resistance and performance of buildings. Thus, a structure built a few years ago may not satisfy current design criteria.

To evaluate the earthquake vulnerability of existing mission-essential, critical, and other selected structures, the Naval Civil Engineering Laboratory (NCEL) has developed the Rapid Seismic Analysis (RSA) procedure.[1] The RSA procedure, a series of computer programs, will identify buildings which may be severely damaged during earthquakes by using the building site's current ground motion criteria and existing structural properties of the framing systems of the building. Any inadequate structure is identified and analyzed in detail to determine the degree of strengthening required and the estimated cost to eliminate or reduce the potential earthquake damage and hazards so that interruption of the facility's mission immediately after an earthquake will be minimal. Then, the results of the detailed analysis are used to make administrative decisions about the disposition of the existing inadequate buildings. The Navy has used the RSA procedure successfully at several of its installations, such as Long Beach Naval Shipyard, Long Beach, CA; Naval Station and Naval Training Center, San Diego, CA; Naval Construction Battalion Center, Port Hueneme, CA; and Naval Facilities, Guam, Mariana Islands.

As part of its continuing seismic research program, the U.S. Army Construction Engineering Research Laboratory (CERL) requested that NCEL evaluate the earthquake vulnerability of selected essential and high-potential-loss buildings at Fort Ord, CA, using the RSA procedure.[2]

The objective of CERL's seismic research is to develop a facility seismic indexing/prioritizing system to economically identify and evaluate the seismic capacity and strengthening strategies for essential and high-potential-loss facilities at Army installations. The preliminary evaluations of the seismic vulnerability of selected buildings at Fort Ord, CA, using NCEL's RSA procedure and the identification of potential enhancements to the RSA procedure are an integral part of CERL's on-going research.

The primary mission of Fort Ord is to support the 7th Infantry Division of the U.S. Army. In addition, it provides support to the Combat Development Experimentation Command, the Defense Language Institute, and active and reserve military programs in Central and Southern California. Moreover, in the event of an earthquake in the San Francisco Bay area, Fort Ord will support disaster relief operations in accordance with the Sixth U.S. Army Earthquake Response Plan–San Francisco Bay Area.

Fort Ord (Figure 1) is located in one of the highest seismicity areas in California. The largest earthquake-induced ground motions at the site are expected from movement along one of the following three active geologic fault zones adjacent to the site:

1. San Andreas fault zone

2. Palo Colorado-San Gregorio fault zone

3. Monterey Bay fault zone.

The San Andreas fault zone is about 25 miles east of the site and the Palo Colorado-San Gregorio fault zone is about 14 miles (22.4 km) southwest of it. The Monterey Bay fault zone is about 3 miles (4.8 km) northwest of the site. The primary hazards to the post's buildings and their occupants from a major movement along one of these fault zones are falling debris from the buildings and damage to the buildings from earthquake ground-shaking.

Objective

The objectives of this study were: (1) to investigate and evaluate the seismic vulnerability of 17 selected

[1] T. K. Lew and S. K. Takahashi, *Rapid Seismic Analysis Procedure*, Technical Memorandum M-51-78-02 (Naval Civil Engineering Laboratory, April 1978).

[2] Lew and Takahashi.

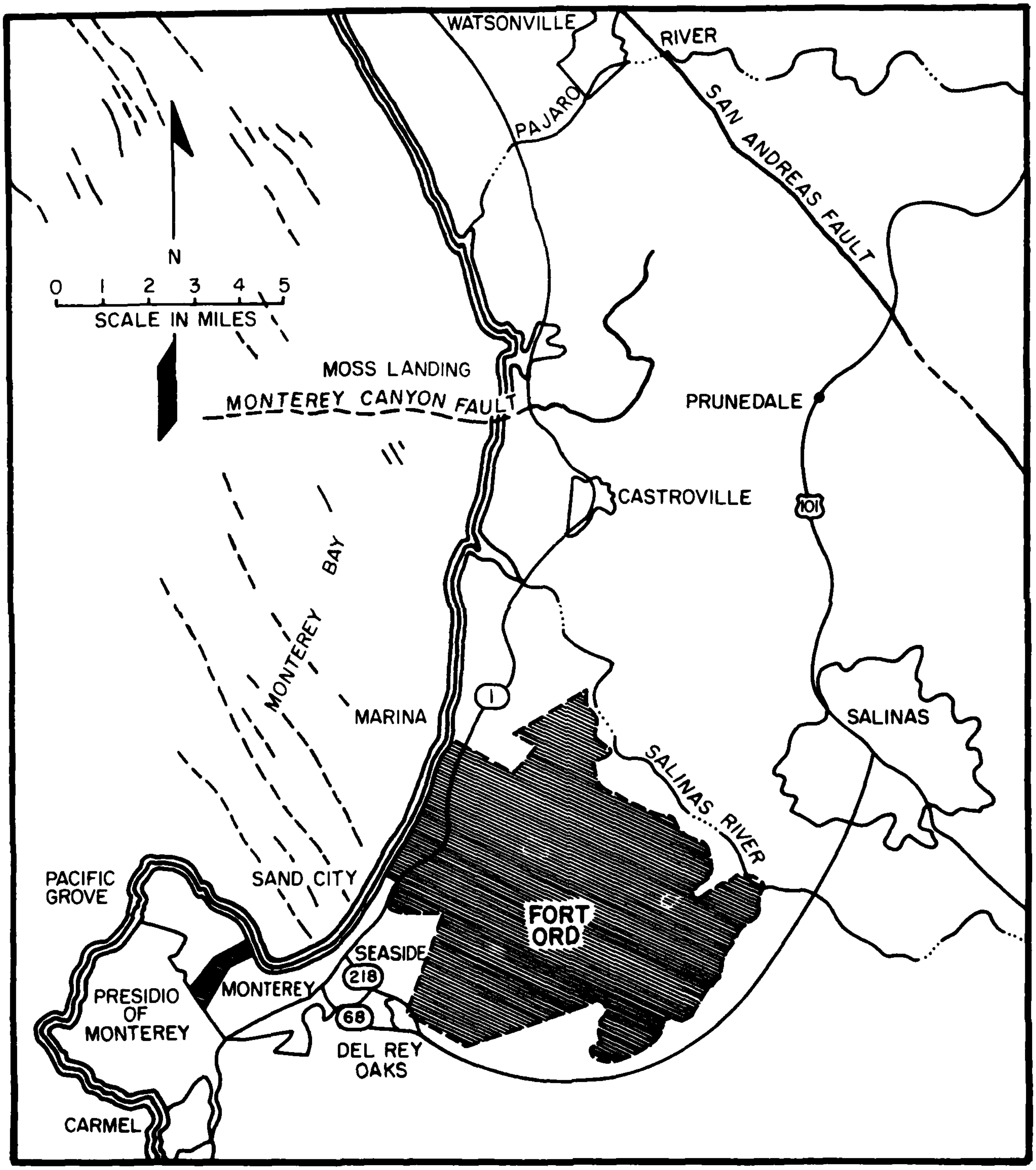


Figure 1. Location map for Fort Ord, CA.

essential and high-potential-loss buildings at Fort Ord, CA, using the RSA procedure, and (2) to recommend modifications to the RSA procedure which would enhance its accuracy or capabilities.

Approach

Seventeen selected buildings were analyzed with the RSA procedure using site elastic response spectra provided by CERL. Based on NCEL's experience, modifications that would enhance the accuracy or capabilities of the RSA procedure were presented and, where appropriate, incorporated into the analysis of the buildings.

Scope

The information provided by this preliminary evaluation is limited to the rapid, approximate analysis of the earthquake ground-shaking effects on the buildings studied.

Mode of Technology Transfer

It is recommended that the information in this report be used to prepare an updated volume of TM 5-809-10, *Seismic Design for Buildings*.

2 ANALYSIS

The major steps of the RSA procedure are: (1) selecting the buildings to be studied; (2) visually inspecting the current physical condition of the buildings; (3) determining the pertinent structural properties, such as the base shear capacities and natural periods at yield and ultimate levels; and (4) inputting the base shear capacities, natural periods, assumed damping values, and current replacement cost for each building and the digitized site response spectra (Figure 2) into a computer program. The program determines the estimated damage and associated cost for each building at the maximum ground acceleration (MGA) for the site of 0.40 g and at site MGAs between 0.05 g and 0.50 g at 0.05-g intervals. The estimated damage is determined from the base shear capacities of the building and the demand from the site response spectra, using the assumed damping values and computed natural periods for the building. In calculating the combined damage for each building, the computer program first figures the estimated damage for each principal direction of the building, based on the

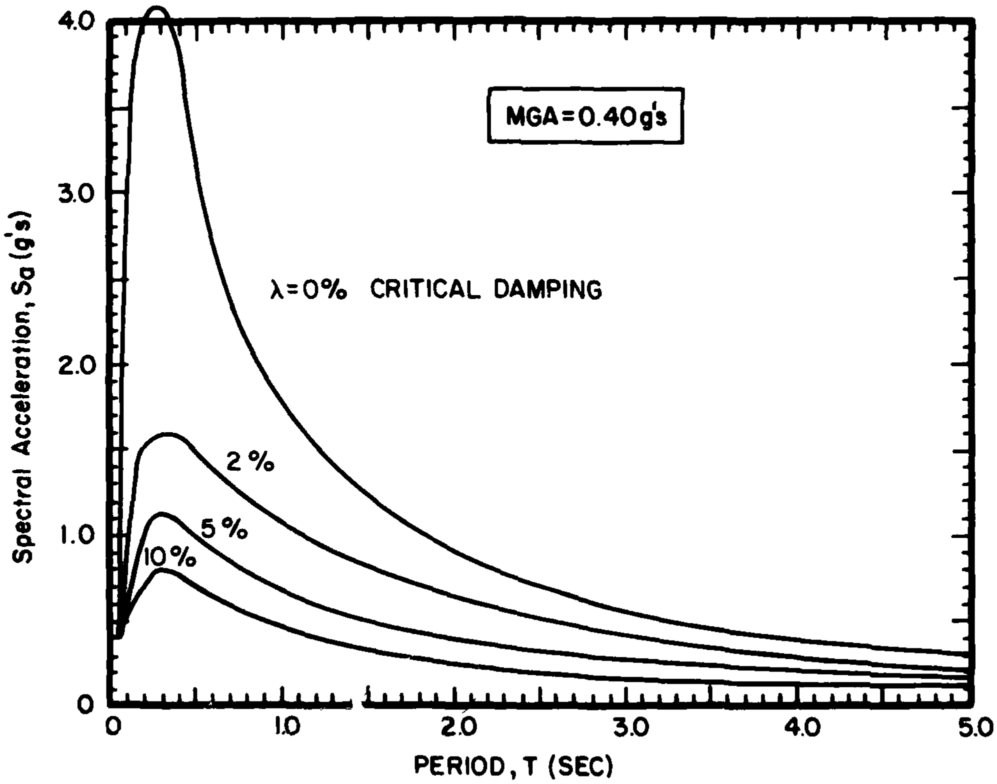


Figure 2. Elastic response spectra for Fort Ord, CA.

demands from the response spectra for the input natural period and damping values. It then determines the combined damage by taking the sum of two-thirds of the damage for the critical direction, and one-third of the damage for the other direction. The estimated damage cost is obtained by multiplying the estimated damage by the replacement cost of the building.

Good engineering judgment, familiarity with the behavior of different buildings under earthquake ground shaking, and familiarity with good seismic-resistant design and construction practices are essential in obtaining realistic damage estimates with the RSA procedure.

Seventeen buildings (see Table 1) representative of typical construction types found at Ford Ord were chosen for analysis by CERL in conjunction with the Fort Ord Facilities Engineer; the choice was made based on the buildings' importance to potential post-disaster recovery requirements, occupancy, cost, age, and number of similar or identical buildings.

Buildings Analyzed

Most of the selected 17 buildings are constructed of reinforced concrete (R/C) and/or reinforced concrete unit masonry (CMU) and were built between 1943 and 1979. One building is constructed of structural steel frames, and a few other buildings have partial steel framing. The footings of many of the buildings are tied together with grade beams or tie-beams designed for a percentage of the axial load on the connected foundations. Experience indicates that this foundation system has performed quite well during past earthquake ground motions in minimizing differential settlement damage to the building from ground shaking.

Table 1
Buildings Analyzed at Fort Ord, CA

Building No.	Description
507	Flight Maintenance Aircraft Hangar
2075	Enlisted Men's Service Club
3620	Enlisted Personnel Barracks W/O Mess
3641	Enlisted Personnel Mess
3701	Unit Chapel
3702	Theater W/O Stage
3703	Enlisted Men's Service Club
4200	Fire Station
4235	Exchange, Main Retail Store
4240	Commissary
4250	Telephone Exchange
4260	Open Mess, NCO
4280	Post Chapel
4471	Enlisted Personnel Barrack W/O Mess
4480	Gymnasium
4782	Enlisted Personnel Barracks W/Mess
4953	Confinement Facility

Figure 3 shows the locations of all of these buildings except Building 507, which is located away from the main garrison. There are three identical types of barracks buildings, i.e., 10 buildings identical to Building 3620,* 10 buildings identical to Building 4471, and 31 buildings identical to Building 4782 on the post.

Descriptions of the buildings analyzed are provided in Table 2, including the year built, number of stories, floor area, replacement cost, type of construction, and primary lateral force resisting systems.

Visual Survey

A quick visual survey was made of each building to determine the physical condition of the buildings, as well as verify the details shown in the construction drawings and the assumptions made in computing the building properties. Results indicated that the buildings were constructed as shown in the construction drawings and are generally in good to excellent physical condition with only minor cracks from thermal expansion, contraction, and shrinkage, except for those discussed below. The interiors of Buildings 3641, 3702, and 3703 were not inspected because they were closed during the survey. Appendix A shows selected photos of the buildings taken during the visual survey.

Building 3620 Enlisted Personnel Barracks Without Mess

The exterior stucco cover over the thermal insulation placed outside of the precast concrete wall panels had numerous horizontal cracks 10 to 15 ft (3 to 45 m) long, and about 1/64 in. (.4 mm) wide. At one location, some triangular pieces of stucco, measuring about 1 ft (.3 m) (nominal) on each side, had fallen off or been punched in. Except for potential hazards from debris falling on personnel near the building during an earthquake, the cracked stucco is expected to have negligible effect on the building's seismic resistance.

The walls were constructed of 6-in. (152-mm)-thick, precast, reinforced concrete panels. Only the vertical boundary reinforcements of the wall panels near the edges of the building and exits were welded to one another at the different floor levels. The other vertical reinforcement from the walls is held in place by the one No. 4 rebar that acts as a continuous chord around

*Eight more buildings of identical design with slightly improved connection details are being constructed at the post.

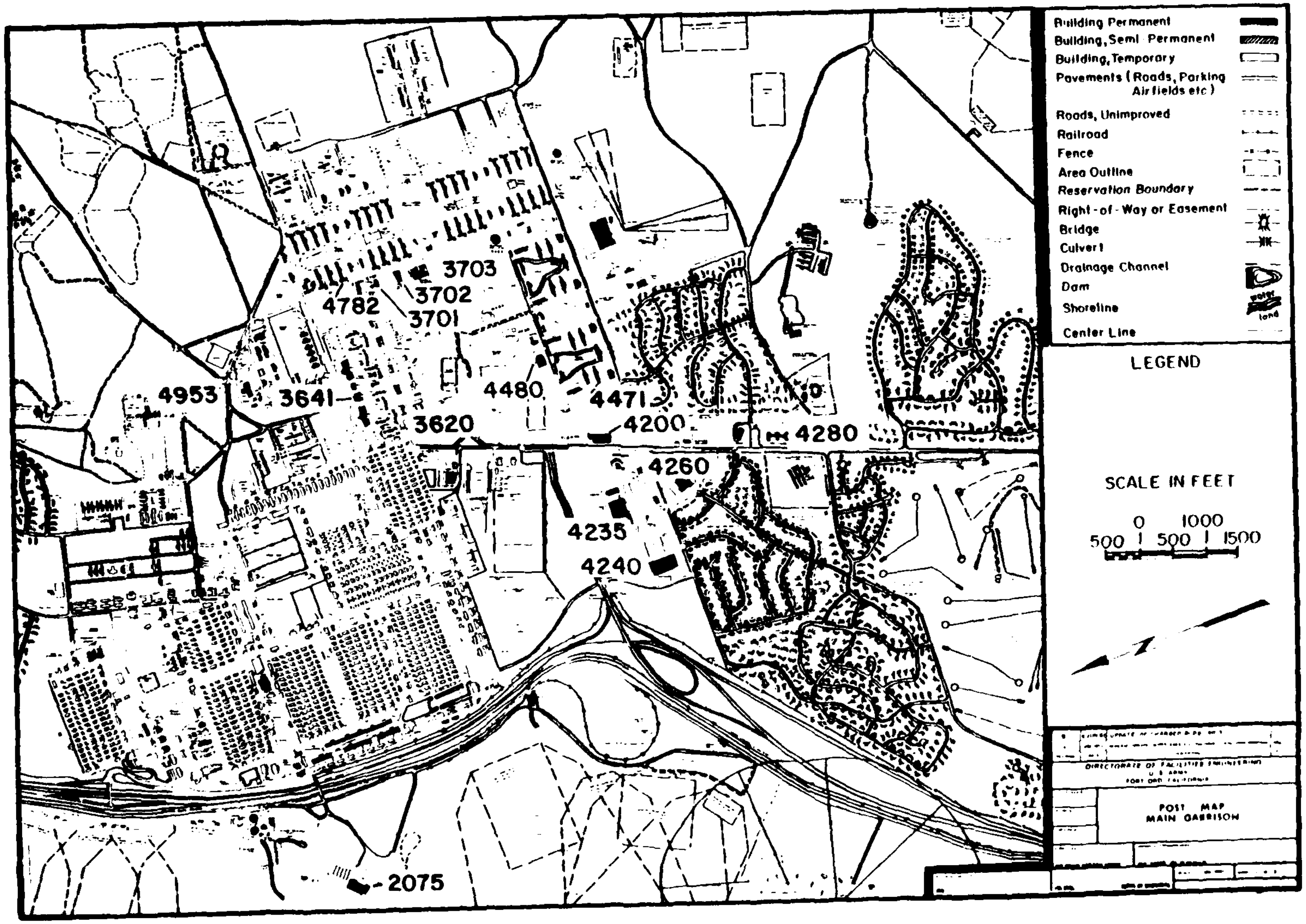


Figure 3. Location of buildings analyzed in the main garrison, Fort Ord, CA.

Table 2
Description of Buildings Analyzed at Fort Ord, CA

Building No.	Year Built	No. of Stories	Total Area (Sq. Ft.)	Replacement Cost ($K)	Type	Lateral Force Resisting System
507	1979	2	64,920	2,926	CMU* & Steel	CMU shear walls and steel frames with X-braces
2075	1943	3	51,892	3,649	R/C** W/Wooded Roof	R/C shear walls and frames
3620	1977	3	22,439	1,332	Precast Concrete & CMU	Precast concrete shear panels and CMU shear walls
3641	1978	1	13,787	1,614	CMU & Steel	CMU shear walls
3701	1977	1	7,820	753	CMU & Glu-lam Wooden Arches	CMU shear walls and R/C frames
3702	1958	1	14,481	1,325	CMU & R/C	CMU shear walls and R/C frames
3703	1962	1	31,770	2,252	CMU & Steel	CMU shear walls and steel rigid frames
4200	1953	1	6,797	468	R/C & CMU	R/C and CMU shear walls and R/C frames
4235	1970	1	72,709	4,617	Steel	Steel frames
4240	1973	1	80,590	4,309	Precast Concrete & Steel	Precast concrete exterior shear walls and steel interior frames
4250	1953	3	13,088	1,140	R/C & CMU	R/C and CMU shear walls
4260	1965	1	35,612	2,670	CMU, R/C, & Steel	CMU shear walls, R/C columns, and steel frames
4280	1958	1	24,670	2,209	CMU Walls, R/C Frames, & Wooden Glu-lam Arches	CMU shear walls
4471	1970	3	40,587	2,409	CMU & R/C	CMU shear walls
4480	1970	1	20,457	1,677	CMU & Steel	CMU shear walls
4782	1954	4 (barracks) 1 (mess)	42,017	2,493	R/C	R/C shear walls and frames
4953	1953		55,487	4,070	R/C	R/C shear walls and frames

*Concrete Masonry Unit (CMU)
**Reinforced Concrete (R/C)

the perimeter of the building. The No. 4 rebar is held in place by reinforcement hooks from the 2-1/2-in. (64-mm)-thick, cast-in-place topping placed on the 2-1/2-in. (64-mm)-thick precast concrete filigree panels. The vertical intersections of the precast wall panels at the building perimeter appeared to be bonded only by non-shrink grout. The 6-in. (152-mm)-thick interior masonry partitions are connected to the precast wall panels by rod anchors installed at 48 in. (1219 mm) on centers. In general, the wall connections throughout the buildings are relatively poor.

Building 3702 Theater Without Stage

There were no signs of cracks on the exterior concrete masonry walls or R/C columns. There appeared to be about a 3-ft (.9-m)-long crack at the construction joint on the outside of the south wall near the top of the third column from the narrow end of the building.

Building 4235 Main Exchange Retail Store

The exposed steel frames on the north wall of the building are badly rusted and need sand blasting and painting. Because the available structural drawings for this pre-engineered building did not show the details needed for the RSA, measurements were taken at the base of one of the steel frames in front of the store during the visual survey to obtain the information needed for the analysis.

Building 4240 Commissary

Some of the exterior precast concrete wall panels of the building had numerous horizontal cracks about 1/64 in. (.4 mm) wide spaced at about 12-in. (305-mm) intervals. Apparently, these horizontal cracks were caused by inadequate concrete cover over the steel reinforcement in the panels. The surfaces of the precast concrete columns have numerous 1/4-in. to 1/2-in. (6-mm to 12-mm) air pockets, indicating that the concrete mix was a bit stiff during pouring.

The construction drawings indicate that the ties for the precast exterior R/C columns supporting the wall panels are inadequate to prevent the four longitudinal rebars from buckling after the concrete shell has

spalled during earthquake response. These ties do not form the usual closed rectangular hoop. They consist of "U" shapes with a flat base and a small portion of each upright is bent at 90° toward one another. The individual footings under the precast R/C columns on the perimeter of the building are tied to one another only through the 40-ft (12-m)-long precast wall panels that span the R/C columns. Individual footings with such connections tend to offer inadequate protection from damage caused by earthquake-induced differential settlement. Also, the structural detailing of the connections of the wall panel intersections at the corners of the building appears inadequate.

The interior framing of the building was fabricated from steel trusses and columns. The structural detailing of the steel framing shown on the drawing appears to be adequate.

Building 4250 Telephone Exchange

The exterior R/C walls have only minor thermal and/or shrinkage cracking. The switching and cable racks on the first floor are well-anchored to the walls and floor. The masonry walls on the second floor are not carried down continuously to the first floor and basement. There are no continuous paths to transfer the lateral earthquake forces on these second-floor walls to the foundation. Experience from past earthquakes indicates that buildings with such interior partitions tend to suffer excessive damage. The basement was not analyzed.

Building 4480 Gymnasium

There are no cross braces under the metal roof deck. There appears to be a 6- to 8-ft (1.8- to 2.4-m) horizontal crack at the bottom of the R/C cap beam on the northwest corner of the basketball court. This crack was probably caused by an unclean construction joint and thermal and/or shrinkage stresses. The construction drawings indicate that the R/C cap beams tie the masonry walls at the perimeter of the building together.

Building 4782 Enlisted Personnel Barracks With Mess

The barracks is a four-story structure which includes a basement. The mess is a separate one-story structure. The concrete surfaces on the exterior of the building have numerous, approximately 1/4- to 1/2-in. (6- to 12-mm) air pockets (see Appendix A). These air pockets indicate that the concrete mix was too stiff when it was poured. There are also a few cracks about 1/2-in. (12-mm) wide on the exterior column surfaces where some of the concrete has spalled off, exposing the steel reinforcing. This was apparently caused by insufficient concrete cover over the rebar.

Inside the building, there are numerous cracks about 1/64 in. (.4 mm) wide on the bottom of the floor slabs at the different floor levels. These cracks, which are perpendicular or parallel to the floor joists, appeared to be caused by thermal and/or shrinkage stresses.

There are 31 of these barracks with mess at the post.

Building 4953 Confinement Facility

This building was inspected from outside the fencing which surrounds the facility. The concrete surfaces of the building appeared to be crack-free and in good condition. The construction drawings indicate that the construction joints for the columns are located at the top of the floor slab at the ground floor and at the bottom of the beams at the upper levels. Experience indicates that the location of these construction joints can lead to excessive damage from earthquake ground-shaking.

Structural Properties

The Ford Ord Facilities Engineering staff provided NCEL with available architectural and structural drawings for the buildings. Structural calculations were not available. The structural drawings were reviewed to determine the primary lateral force resisting systems of each building and the building properties needed to perform the rapid seismic analysis. These properties included the base shear capacities and natural periods at the yield and ultimate levels for each principal direction of the building (i.e., longitudinal and transverse).

This section presents the assumed damping values and the computed base shear capacities and natural periods of the buildings analyzed. The material strengths and procedures used were essentially identical to those presented by Lew and Takahashi. However, some of the material strengths and procedures were modified to enhance the accuracy of the rapid seismic analysis procedure by better reflecting the current condition of the building. The following text briefly discusses the rationale for the modifications.

Damping Values

Table 3 gives the assumed damping values used in the analysis. Except for the steel buildings, the values are identical to those given by Lew and Takahashi.

The assumed damping values for steel buildings at yield and ultimate levels were increased from 2 percent and 5 percent of critical to 5 percent and 10 percent of critical, respectively, in the analysis. This change was made in conformance to those values recommended for

Table 3
Assumed Damping Values

Building Type	Percentage of Critical Damping	
	Yield	Ultimate
Steel	5	10
Concrete	5	10
Masonry	5	10

the design of a new steel building by Chopra and Newmark.[3] Another reason for increasing the assumed damping values was to lower the demand from the response spectra.

Increasing the assumed damping values as indicated would decrease the demands on the building by about 25 percent (see Figure 2). Experience with the RSA procedure indicates that in actual major earthquakes, the damage estimates for steel buildings are generally too high in comparison to those observed for similarly constructed buildings. Reducing the demand from the response spectra would reduce the estimated damage for steel buildings. However, the damage estimate is not directly proportional to the reduction in demand. Even with this demand decrease, the damage estimates for steel buildings are still much higher than those observed for similarly constructed buildings during actual major earthquakes.

To further reconcile the damage estimates for steel buildings from the RSA procedure with damages observed under actual earthquake conditions, the ultimate demands from the elastic response spectra are decreased by the introduction of a reduction factor, R = 5.* The reduction factor R is used to account for energy absorption and dissipation from the inelastic response of the building under the earthquake ground motions that were not accounted for by lengthening the natural periods and increasing the damping from the yield to the ultimate level. This energy absorption and dissipation comes from (1) the work done as defined by the area under the load deformation hysteresis curve of the lateral force resisting elements of the building, and (2) the work done during stress redistribution when the forces on the overloaded elements are distributed to the adjacent redundant lateral force resisting elements that are not overloaded.

Base Shear Capacities

Table 4 gives the computed base shear capacities at yield and ultimate levels for the longitudinal and transverse directions of the buildings. Buildings 4280 and 4782 were analyzed as three and as two separate buildings, respectively, due to the presence of seismic spacing or actual building separations:

Building	Description
4280A	Chapel
4280B	North Education Wing
4280C	South Education Wing
4782A	Mess (one-story)
4782B	Barracks (four stories, including basement)

In computing the base shear capacities for the reinforced concrete (R/C) and reinforced masonry buildings, the ultimate value was computed first. The yield value was computed by dividing the ultimate value by a load factor of 1.5. This modification was done in an attempt to lower the estimated damage and to conform to the load factor used in the American Concrete Institute's (ACI) ultimate strength design procedure. Using a load factor of 1.5 implicitly assumes that the overall yielding of the lateral force resisting system(s) of the building occurs at two-thirds of ultimate base shear capacity. It is expected that some of the building's lateral force resisting elements would have yielded (cracked) before the demand from the earthquake ground motion reaches two-thirds of the building's ultimate base shear capacity. By contrast, the procedure given by Lew and Takahashi assumes that the R/C and reinforced masonry lateral force resisting elements of a building cracks (yields) at one-third of its ultimate strength. Experience indicates that increasing the yield capacity relative to the ultimate capacity by using the load factor concept provides a lower and more realistic estimate of earthquake damages for R/C and reinforced masonry buildings.

The values in Table 4 indicate that the yield level base shear capacities of the buildings range between 0.11 g and 2.15 g. The inherent nature of many of the single-story reinforced masonry buildings causes their base shear capacity at yield to exceed 1.0 g. Exterior masonry walls protect the building occupants and contents from the climate. Interior masonry partitions satisfy other functional requirements. Although many of these walls may not have been designed as part of the building's lateral force resisting system,

[3]A. Chopra and N. Newmark, *Design of Earthquake Resistant Structures*, Chapter 2, "Analysis," Emile Rosenbleuth, ed. (John Wiley and Sons, 1980).

*A reduction factor of R = 5.0 is recommended for wooden buildings. For R/C buildings with better than average reinforcement detailing, R = 1.5 is recommended. For other R/C buildings, R = 1.0 should be used.

Table 4
Base Shear Capacities of Buildings Analyzed at Fort Ord, CA

Building No.	Base Shear Capacities (g) Yield Longitudinal	Yield Transverse	Ultimate Longitudinal	Ultimate Transverse
507	0.63	0.41	0.94	0.61
2705	1.06	0.82	1.62	1.25
3620	0.43	0.47	0.65	0.73
3641	1.95	1.07	2.73	1.50
3701	1.11	0.94	1.67	1.41
3702	0.77	0.67	1.92	1.76
3703	1.82	1.07	2.55	1.50
4200	1.07	1.17	1.60	1.76
4235	0.11	0.13	0.17	0.20
4240	0.59	0.61	0.92	0.94
4250	0.71	0.40	1.07	0.60
4260	1.00	1.13	2.73	2.92
4280A	1.54	2.15	1.01	1.42
4280B	1.46	0.89	2.04	1.23
4280C	1.71	1.71	2.40	2.40
4471	0.38	0.17	0.64	0.41
4480	1.60	0.89	2.40	1.33
4782A	1.05	0.86	1.61	1.33
4782B	0.14	0.27	0.30	0.49
4953	0.83	0.52	1.57	1.09

essentially all of them participate in the building's response to the earthquake motions. This is because they were not designed and constructed as isolated walls. The lowest base shear capacity at yield belongs to one of the steel buildings in the group (Building 4235, the Post Exchange Main Retail Store). The base shear capacities for the buildings at ultimate range between 0.17 g and 0.20 g.

The primary lateral force resisting systems of Buildings 3620 and 4240 consisted of precast concrete wall panels. The computed base shear capacities of these buildings were based on the effective area of the panels and not the connections.*

Experience from past major earthquakes indicates that precast concrete buildings have generally performed poorly because of their poor connection detailing. The connections used in the two buildings are no exception. Thus, the computed base shear capacities for these two buildings were reduced by 40 percent to reflect the poor performance of the connections. The 40 percent reduction is based on engineering judgment. The capacities for the two buildings shown in Table 4 have been reduced by 40 percent.

Natural Periods

Table 5 gives the computed natural periods for the buildings analyzed. These periods were computed as shown in the RSA procedure documented by Lew and Takahashi, except for the R/C shear wall buildings. For these R/C buildings, the formula

$$T_y = \frac{0.05\, h_n}{\sqrt{D}} \qquad \text{[Eq 1]}$$

where:

T_y = natural period at yield (sec)

h_n = height of building (ft)

D = base width of building in direction considered (ft)

was used instead of Eq 5.9, $T_y = 0.5\,(0.05h_n/\sqrt{D})$, given by Lew and Takahashi.[4] Experience indicates that the periods computed using Eq 5.9 are much lower than those obtained from detailed analysis. Because the natural periods of most low-rise R/C shear wall

*It is not possible to compute the strength of these connections without a detailed analysis. Even the results from such an analysis may only be approximate.

[4]T. K. Lew and S. K. Takahashi, *Rapid Seismic Analysis Procedure*, Technical Memorandum M-51-78-02 (Naval Civil Engineering Laboratory, April 1978).

Table 5
Natural Periods of Buildings Analyzed at Fort Ord, CA

Building No.	Natural Periods (sec) Yield Longitudinal	Yield Transverse	Ultimate Longitudinal	Ultimate Transverse
507	0.09	0.14	0.15	0.23
2075	0.06	0.08	0.09	0.12
3620	0.19	0.18	0.29	0.28
3641	0.06	0.06	0.09	0.09
3701	0.09	0.13	0.10	0.14
3702	0.08	0.10	0.09	0.11
3703	0.06	0.07	0.09	0.10
4200	0.06	0.08	0.10	0.12
4235	0.29	1.21	0.53	2.22
4240	0.08	0.10	0.12	0.16
4250	0.05	0.10	0.08	0.15
4260	0.030	0.030	0.031	0.032
4280A	0.11	0.18	0.16	0.26
4280B	0.04	0.06	0.06	0.09
4280C	0.05	0.05	0.09	0.09
4471	0.06	0.14	0.08	0.16
4480	0.09	0.11	0.13	0.16
4782A	0.04	0.06	0.06	0.09
4782B	0.05	0.14	0.06	0.19
4953	0.06	0.08	0.08	0.10

buildings are less than 0.35 sec, the resulting demands estimated from the site response are lower than actual demands (Figure 2). Hence, damage estimates which use Eq 5.9 to compute the periods at yield would be unconservative.

Damage Estimates

The digitized site response spectra, building identifications, assumed damping values, computed natural periods and base shear capacities at yield and ultimate levels for the two principal horizontal directions, and the current (1981) building replacement costs were input into a computer program to determine the estimated damage and associated cost under the maximum site ground acceleration of 0.40 g. The program also computes the damage and cost estimates between 0.05 g and 0.50 g at 0.05-g intervals.

In the damage estimation, the building is assumed to experience no damage when the demand (loading) from the response spectra is less than or equal to the base shear capacity of the building at yield. On the other hand, the building is assumed to experience 100 percent damage when the demand is equal to or greater than the base shear capacity of the building at ultimate. The variation of damage is assumed to be linear between yield and ultimate levels. The program first computes the estimated damage for each of the transverse and horizontal directions of the building. It determines the combined damage by taking the sum of two-thirds of the damage of the critical direction and one-third of the damage for the other direction.* The estimated damage cost is determined by multiplying the building replacement cost by the estimated damage. Appendix B gives a complete set of the damage and cost estimates.

For illustration, Table 6 presents the computer output for Building 4250. The computer program prints the interpolated demands from the site response spectra (Figure 2) in addition to the building's input periods, damping values, and base shear capacities. The printed site demands at ultimate included the effects of the reduction factor, R. At the site MGA of 0.40 g, the estimated total damage for the building is 66.7 percent or $760,000. From the bottom of the table for an MGA of 0.40 g, the damage estimates in the transverse and longitudinal directions are 100 percent and 0 percent. Thus, the building is only seismically inadequate in the transverse direction.

Figure 4 shows a plot of the estimated combined damage versus maximum ground accelerations at the

*This implicitly assumes that the damage experienced by the lateral force resisting elements in the critical direction also reduces their ability to resist seismic forces in the other orthogonal direction.

Table 6
Earthquake Damage Estimates for Building 4250, Telephone Exchange at Ford Ord, CA

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4250 TELEPHONE EXCHANGE

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.100	.05	.400	.680	
ULTIMATE LEVEL	.150	.10	.600	.622	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.050	.05	.710	.443	
ULTIMATE LEVEL	.080	.10	1.070	.473	1.000

BUILDING REPLACEMENT COST $ 1140000.

ESTIMATED TOTAL DAMAGE TO BUILDING 66.7 PERCENT

ESTIMATED COST OF DAMAGE $ 760000.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.085	.078	0.0	.055	.059	0.0	0.0	0
.10	.170	.155	0.0	.111	.118	0.0	0.0	0
.15	.255	.233	0.0	.166	.177	0.0	0.0	0
.20	.340	.311	0.0	.221	.236	0.0	0.0	0
.25	.425	.389	10.6	.277	.295	0.0	7.0	80
.30	.510	.466	45.1	.332	.355	0.0	30.1	342
.35	.595	.544	77.7	.387	.414	0.0	51.8	590
.40	.680	.622	100.0	.443	.473	0.0	66.7	759
.45	.765	.699	100.0	.498	.532	0.0	66.7	759
.50	.850	.777	100.0	.553	.591	0.0	66.7	759

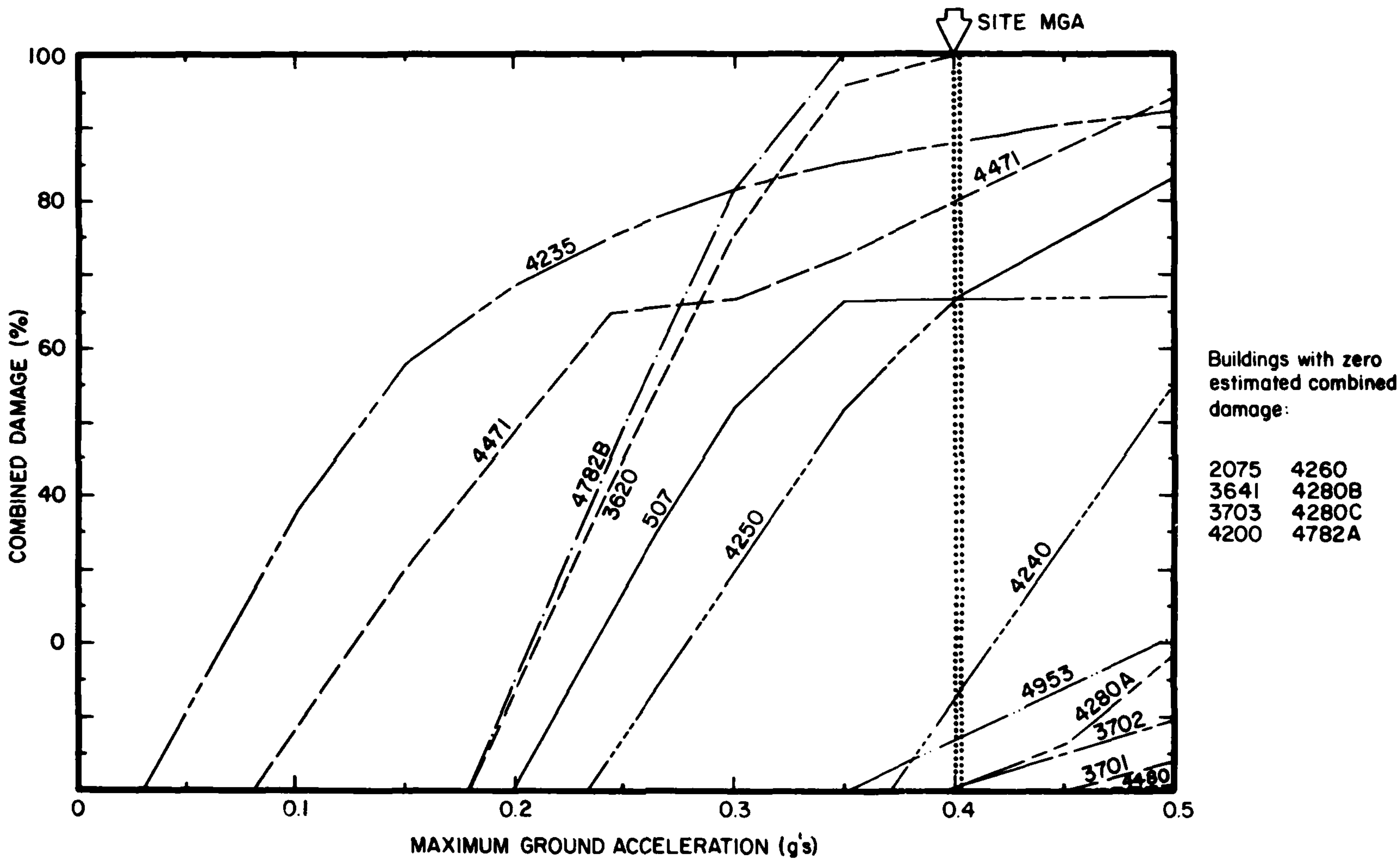


Figure 4. Estimated combined damage versus maximum ground acceleration for buildings analyzed at Fort Ord, CA.

site for the buildings analyzed. The curves for the more seismic-resistant buildings are near or coincide with the horizontal site MGA axis. The curves for the less resistant buildings have a relatively large initial slope and are close to the vertical damage axis. At the site MGA of 0.40 g. Buildings 2435, 4471, 4782B, 3620, 507, and 4250 each have estimated combined damage of greater than 60 percent. Thus, these buildings are expected to have a high probability of being severely damaged or of collapsing under the maximum ground accelerations at the site. Table 7 shows the damage estimates for the buildings analyzed. The data include damage estimates for the transverse and longitudinal direction of each building.

Table 8 summarizes estimated damage costs from the computer output for the buildings analyzed at site MGAs between 0.05 g and 0.50 g in 0.05-g intervals. The estimated total damage cost at the site MGA of 0.40 g is $13.0 million. Because there are 9, 9, and 30 additional buildings, respectively, which are identical to Buildings 3620, 4471, and 4782 at the post, the estimated damage would become $114.7 million when the identical buildings are included, as shown in Table 9.

In addition to engineering judgment, the curves shown in Figure 4 were used to help determine which buildings would require detailed analysis. The criteria used to select these buildings were:

1. Buildings with greater than or equal to 60 percent estimated combined damage under the maximum earthquake ground acceleration at the site would definitely require detailed analysis.

2. Buildings with between 30 percent and 60 percent estimated combined damage may require detailed analysis, depending on engineering judgment.

3. Buildings with relatively poor structural connections would require detailed analysis, even if the estimated damage is less than 30 percent.

In applying criteria 2 and 3, the analyst should be familiar with good current seismic design and construction practices so that he/she can judge the seismic adequacy of the layout of the lateral force resisting system and the detailing of the structural connections of the building considered. In applying criterion 2, computing the equivalent current code base shear capacities for the building and comparing them with the corresponding code-required design base shear coefficients were found to be helpful.

Based on the above criteria, analysts recommended that Buildings 4235, 4782B, 3620, 4471, 507, 4250, and 4240 be analyzed in detail to determine the degree of strengthening and cost required to reduce the seismic hazards to these buildings and their occupants. These buildings are given in approximate order of priority. Although Building 4240 has an estimated damage of 12.6 percent, it was recommended for detailed analysis because of its relatively poor concrete reinforcement detailing, particularly the inadequate ties for the precast columns.

Table 7
Summary of Damage Estimates
at 0.40 g Maximum Ground Acceleration
for Buildings Analyzed at Fort Ord, CA

Building No.	Estimated Damage Transverse	Longitudinal	Combined
507	100.0	0.9	66.9
2075	0.	0.	0.
3620	100.	100.	100.
3641	0.	0.	0.
3701	0.	0.	0.
3702	0.8	0.	0.5
3703	0.	0.	0.
4200	0.	0.	0.
4235	74.4	95.1	88.2
4240	18.8	0.	12.6
4250	100.0	0.	66.7
4260	0.	0.	0.
4280A	0.	0.	0.
4280B	0.	0.	0.
4280C	0.	0.	0.
4471	100.0	39.7	79.9
4480	0.	0.	0.
4782A	0.	0.	0.
4782B	100.0	100.0	100.0
4953	10.1	0.0	6.7

Strengthening Costs

It is very difficult to estimate strengthening costs for buildings without an appropriate detailed seismic analysis. Even when a detailed seismic analysis has been performed, the unit costs for seismic strengthening can vary tremendously, as shown in Table 10, which is based on limited experience. The large spread in the unit cost for seismic strengthening of buildings of similar size and construction type shows the difficulty in trying to estimate strengthening costs for the buildings in question based on only a rapid seismic analysis. Consequently, the seismic strengthening costs for these buildings were not estimated.

Table 8
Summary of Estimated Earthquake Damage Costs for Buildings
Analyzed at Ford Ord, CA

SUMMARY OF DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS IN G'S

VALUES ARE GIVEN IN THOUSANDS OF DOLLARS

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

	.05G	.10G	.15G	.20G	.25G	.30G	.35G	.40G	.45G	.50G	REPL COST
BLDG 507	0	0	0	14	797	1514	1950	1958	2197	2434	2926
BLDG 2075	0	0	0	0	0	0	0	0	0	0	3649
BLDG 3620	0	0	0	160	609	1003	1276	1331	1331	1331	1332
BLDG 3641	0	0	0	0	0	0	0	0	0	0	1614
BLDG 3701	0	0	0	0	0	0	0	0	0	32	753
BLDG 3702	0	0	0	0	0	0	0	7	67	125	1325
BLDG 3703	0	0	0	0	0	0	0	0	0	0	2252
BLDG 4200	0	0	0	0	0	0	0	0	0	0	468
BLDG 4235	489	1750	2653	3175	3516	3756	3934	4072	4181	4270	4617
BLDG 4240	0	0	0	0	0	0	0	541	1460	2378	4309
BLDG 4250	0	0	0	0	80	342	590	759	759	759	1140
BLDG 4260	0	0	0	0	0	0	0	0	0	0	2670
BLDG 4280A	0	0	0	0	0	0	0	0	47	142	782
BLDG 4280B	0	0	0	0	0	0	0	0	0	0	835
BLDG 4280C	0	0	0	0	0	0	0	0	0	0	592
BLDG 4471	0	201	720	1167	1556	1605	1748	1924	2098	2269	2409
BLDG 4480	0	0	0	0	0	0	0	0	0	10	1677
BLDG 4782A	0	0	0	0	0	0	0	0	0	0	352
BLDG 4782B	0	0	329	1056	1750	2140	2140	2140	2140	2140	2141
BLDG 4953	0	0	0	0	0	0	0	273	573	863	4070
TOTAL	489	1951	3702	5572	8308	10360	11638	13005	14853	16753	39913
PERCENT	1.2	4.9	9.3	14.0	20.8	26.0	29.2	32.6	37.2	42.0	

Table 9
Summary of Estimated Earthquake Damage Costs for Buildings Analyzed at Fort Ord, CA, Including Identical Buildings
(Values Are Given in Thousands of Dollars)

Damage Estimate for Selected Buildings at Fort Ord, California, 11-23-81

	.05G	.10G	.15G	.20G	.25G	30G	.35G	40G	45G	50G	REPL COST
BLDG 507	0	0	0	14	797	1514	1950	1958	2197	2434	2926
BLDG 2075	0	0	0	0	0	0	0	0	0	0	3649
BLDG 3620(10)*	0	0	0	1600	6090	10030	12760	13310	13310	13310	13320
BLDG 3641	0	0	0	0	0	0	0	0	0	0	1614
BLDG 3701	0	0	0	0	0	0	0	0	0	32	753
BLDG 3702	0	0	0	0	0	0	0	0	67	125	1325
BLDG 3703	0	0	0	0	0	0	0	0	0	0	2252
BLDG 4200	0	0	0	0	0	0	0	0	0	0	468
BLDG 4235	489	1750	2653	3175	3516	3756	3934	4072	4181	4270	4617
BLDG 4240	0	0	0	0	0	0	0	541	1460	2378	4309
BLDG 4250	0	0	0	0	80	342	590	759	759	759	1140
BLDG 4260	0	0	0	0	0	0	0	0	0	0	2670
BLDG 4280A	0	0	0	0	0	0	0	0	47	142	782
BLDG 4280B	0	0	0	0	0	0	0	0	0	0	835
BLDG 4280C	0	0	0	0	0	0	0	0	0	0	592
BLDG 4471(10)*	0	2010	7200	11670	15560	16050	17480	19240	20980	22690	24090
BLDG 4480	0	0	0	0	0	0	0	0	0	10	1677
BLDG 4782A(31)*	0	0	0	0	0	0	0	0	0	0	0
BLDG 4782B(31)*	0	0	10149	32736	54250	66340	66340	66340	66340	66340	66371
BLDG 4953	0	0	0	0	0	0	0	3463	17763	26753	126170
TOTAL	489	3760	20052	49195	80293	98032	103054	114690	127104	139243	270472
PERCENT	.18	1.39	7.41	18.19	29.69	36.24	38.10	42.40	46.99	51.48	

*Total number of buildings is given in parentheses.

Table 10
Summary of Strengthening Costs of Buildings From Detailed Seismic Analysis
(Metric Conversion Factors: 1 ft = .3048 m; 1 sq ft = .093m²)

Use	Material	No. of Stories	Size, ft (Overall) Length	Width	Height	Area (Sq. Ft.)	Replacement Cost, $K	Strengthening Costs Total, $K	Unit, $/ft²
Data Center	Precast	1	200	100	18	20,260	1,051	80	3.95
Administration	Wood	2	391	175	26	81,378	2,450	908	12.15
Firehouse	Wood	1	122	87	16, 35T	7,290	201	68	7.00
Warehouse	Steel/Conc.	1	608	200	26	121,600	1,948	1380	11.40
Office/Shop	Steel	1,2	560	220	24, 32	62,470	1,665	920	17.60
Barracks	Conc.	3	222	31	34	20,400	1,119	175	9.00
Marine M.S.	Conc.	5	112	78	107	38,515	4,738	350	10.00
Machine, Tool	Steel	1	600	200	82	125,000	17,260	320	2.56
Administration	Steel	5	308	168	67	258,720	7,792	77	0.30
Serv. Group	Steel	1,2	727	240	40	148,080	11,296	163	1.10
Transportation	Precast	1	672	374	13 to 24	62,078	3,770	2000	33.00
Power Plant	Conc.	1,2,M	170	155	53	41,700	33,626	2500	60.00*
Public Works	Steel	1,M	418	202	28	65,702	709	941	15.00
Power Plant	Conc.	1	348	51	44	9,607	3,241	510	28.00

*Includes cost of bracing power plant equipment.

3 RECOMMENDED MODIFICATIONS FOR THE RSA PROCEDURE

This section presents a list of the recommended modifications to enhance the accuracy and capabilities of the RSA procedure. The modifications were kept as simple as possible so that the procedure's accuracy and capabilities can be enhanced without sacrificing its simplicity. The modifications are based on NCEL's experience with the procedure and the author's judgment. The recommendations are in the following areas: (1) computation of base shear capacities, (2) computation of natural periods at yield level, (3) damping values, (4) computation of estimated damage, and (5) selection of buildings for detailed seismic analysis.

Where appropriate, the modifications were incorporated into the analysis of the selected buildings at Fort Ord. A list and short discussion of the recommended modifications for the RSA procedure follow.

Computation of Base Shear Capacities

Steel Buildings

In analyzing steel buildings, use the actual yield strength of the steel if it is known. If not, assume that the yield strength f_y = 36 ksi (6.25 G Pa) and that the shear strength $f_v \doteq 0.55 f_y$ in the shearing of rivets and bolts.

For the bending about the minor axis of rolled steel H sections or compact sections, use the formulas:

$$M_u = 1.5 M_y \qquad \text{[Eq 2]}$$

and

$$V_{uc} = 1.5 V_y \qquad \text{[Eq 3]}$$

to compute the ultimate moment capacity, M_u, and ultimate shear capacity, V_{uc}, of columns.

R/C and Reinforced Masonry Buildings

In analyzing R/C and reinforced masonry buildings, compute the ultimate base shear capacity first. Then compute the base shear capacity at yield by dividing the ultimate capacity by a load factor of 1.5

Precast Concrete Buildings

In analyzing buildings constructed from precast concrete components, multiply the computed base shear capacities by 0.6 to account for the generally poor behavior of the structural connections of these buildings in past major earthquakes.

Computation of Natural Periods at Yield

Steel, Concrete, or Wood Frame Buildings

No. of Story	Period at Yield
$N = 1$	$2\pi\sqrt{\dfrac{m}{K}}$

where: m = seismic mass

K = lateral stiffness

No. of Story	Period at Yield
$N > 1$	$2\pi\sqrt{\dfrac{\Sigma w_i \Delta_i^2}{g\, \Sigma F_i \Delta_i}}$ *

where: w_i = story seismic weights

F_i = story forces

Δ_i = lateral deflections at story "i" caused by lateral forces F_i

or

No. of Story	Period at Yield
$N \geq 1$	$0.10N$

R/C Shear Wall Buildings

No. of Story	Period at Yield
$N \leq 3$	$0.05\,N$ or $(0.05h_n)/\sqrt{D}$

where: h_n = building height (ft)

D = building base width (ft)

No. of Story	Period at Yield
$N > 3$	$(0.05h_n)/\sqrt{D}$

Damping Values

For steel buildings, assume 5 percent and 10 percent of critical damping at the yield and ultimate levels, respectively.

Computation of Estimated Damage

Steel and Wooden Buildings

Divide the ultimate demand from the elastic site response spectra by a reduction factor (**R** = 5.0) before determining the estimated damage.

R/C Buildings

For R/C buildings with above-average reinforcement detailing, divide the ultimate demand from the site elastic response spectra by a reduction factor (**R** = 1.5)

***This formula is a modified version of the Rayleigh procedure.**

before computing the estimated damage. Do not reduce the site demand *at ultimate for other* R/C buildings.

Selection of Buildings for Detailed Seismic Analysis

Determine buildings that require detailed seismic analysis on the basis of the following criteria:

1. Buildings with greater than 60 percent estimated combined damage when subjected to the maximum ground acceleration at the site would definitely require detailed analysis.

2. Buildings with between 30 percent and 60 percent estimated combined damage may require detailed analysis, depending on engineering judgment.

3. Buildings with relatively poor structural connection detailing would require detailed analysis, even if the estimated damage is less than 30 percent.

Good engineering judgment, familiarity with the behavior of different buildings under earthquake ground shaking, and familiarity with good seismic resistant design and construction practices are indispensable in obtaining realistic damage estimates with the RSA procedure.

4 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn from the RSA of 17 selected essential and high-potential-loss buildings at Fort Ord.

1. Results from the visual inspection and review of construction drawings indicate that, with a few exceptions, the buildings were generally in good to excellent condition with only minor cracks from thermal or shrinkage stresses.

2. Under the site MGA of 0.40 g, the analysis results indicate that Buildings 4235 (Main Retail Exchange); 4471, 4782B, and 3620 (Enlisted Personnel Barracks of different vintage); 507 (Flight Maintenance Aircraft Hangar); and 4250 (Telephone Exchange) each would have an estimated damage greater than 60 percent. These buildings are expected to have a high probability of being severely damaged or collapsing from the earthquake ground shaking at the site.

3. Use of the recommended modifications will enhance the accuracy and capabilities of the RSA procedure. These modifications are for computation of base shear capacities; computation of natural periods at yield, damping values, and estimated damage; and selection of buildings for detailed seismic analysis.

Based on the analysis described in this report, the following recommendations are made:

1. Perform detailed seismic analysis on Buildings 4235 (Main Retail Exchange); 4471, 4782B, and 3620 (Enlisted Personnel Barracks of different vintage); 507 (Flight Maintenance Aircraft Hangar); 4250 (Telephone Exchange); and 4240 (Commissary) at Fort Ord to determine the degree of strengthening and cost required to reduce the seismic hazards of these buildings.

2. Verify the existence of the cracks observed in Buildings 3702 (Theater w/o stage), and 4480 (Gymnasium), and, if necessary, clean and then grout them with suitable epoxy material as a part of normal maintenance. Sandblast and paint the steel frames on the north wall of Building 4235 (Main Retail Exchange).

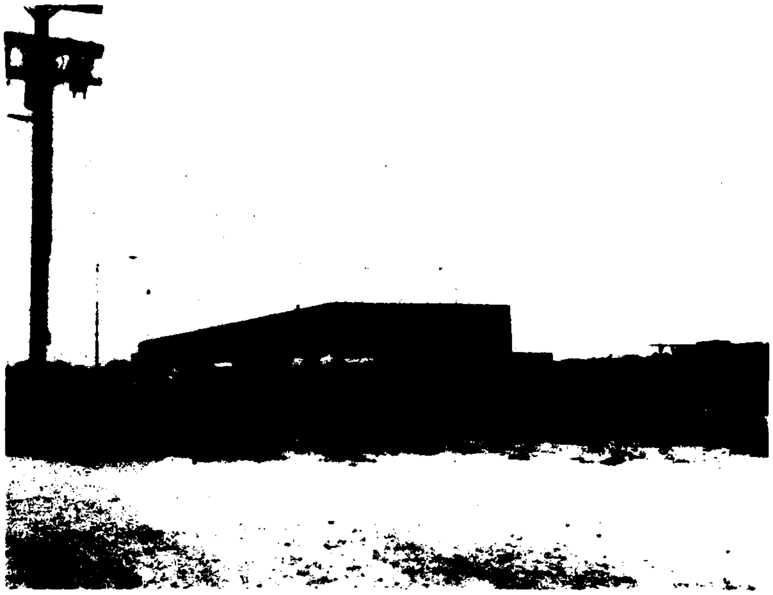
3. Incorporate the list of modifications into the RSA procedure.

REFERENCES

Lew, T. K. and S. K. Takahashi, ***Rapid Seismic Analysis Procedure***, Technical Memorandum M-51-78-02 (Naval Civil Engineering Laboratory, April 1978).

Chopra, A., and N. Newmark, ***Design of Earthquake Resistant Structures***, Chapter 2, "Analysis," Emile Rosenbleuth, ed. (John Wiley and Sons, 1980).

APPENDIX A
PHOTOS OF BUILDINGS ANALYZED



507

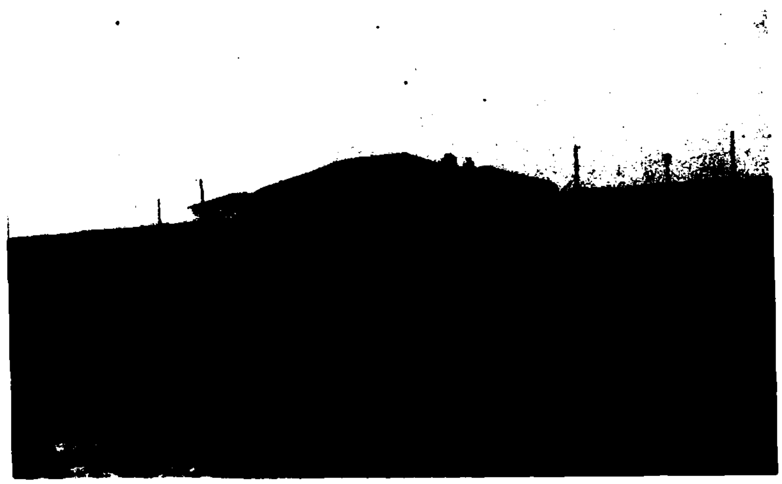
507

Flight Maintenance Aircraft Hanger

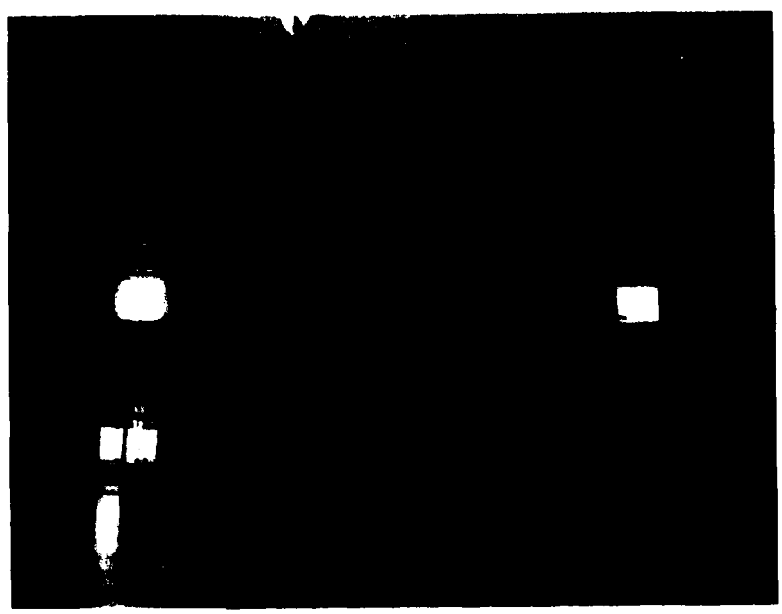
507

507

Flight Maintenance Aircraft Hanger



2075



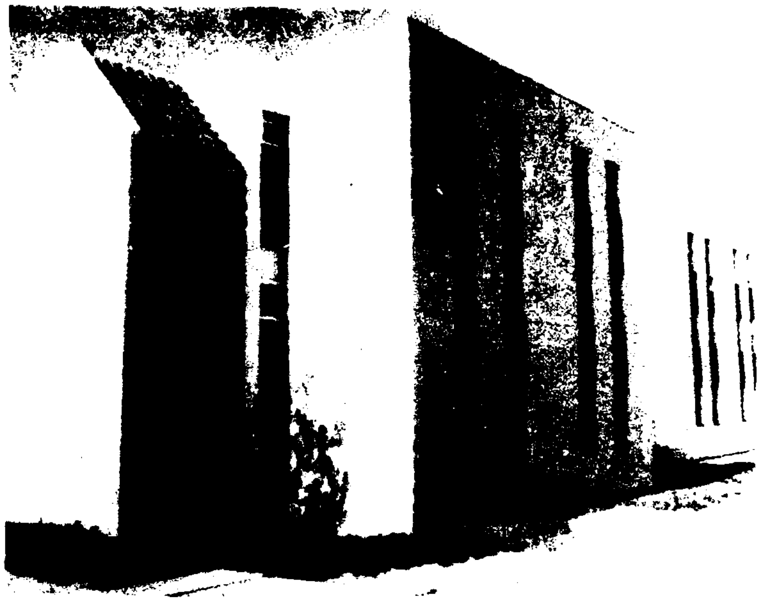
2075

Enlisted Men's Service Club

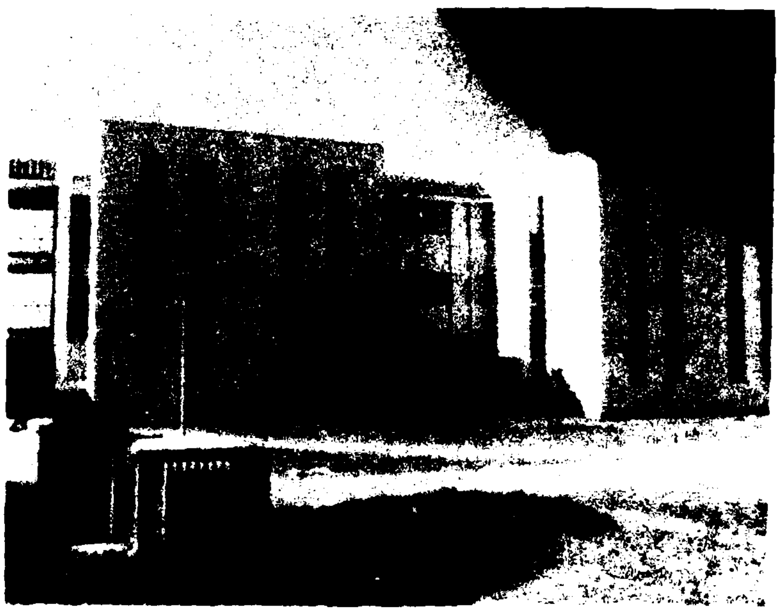
2075

2075

Enlisted Men's Service Club

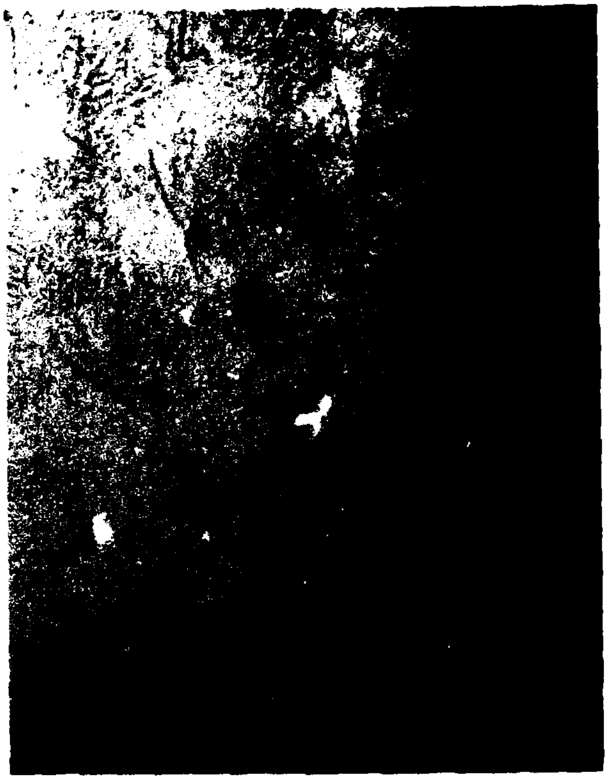


36 20

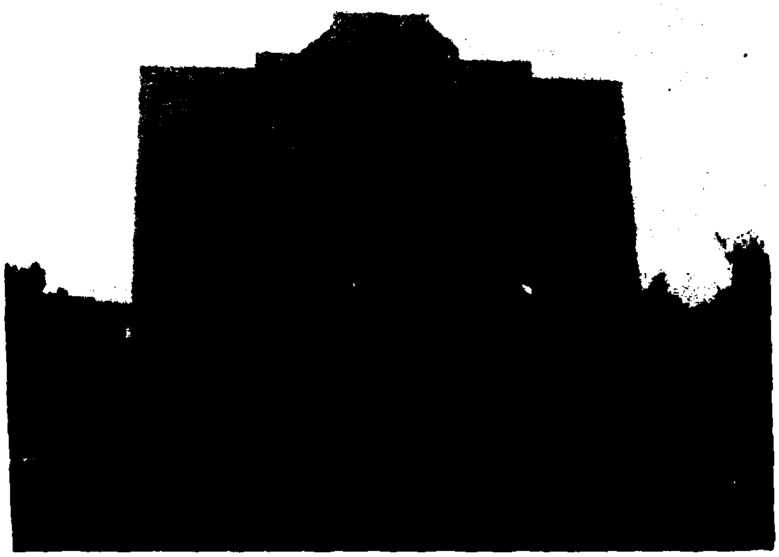


36 20

Enlisted Personnel Barracks Without Mess



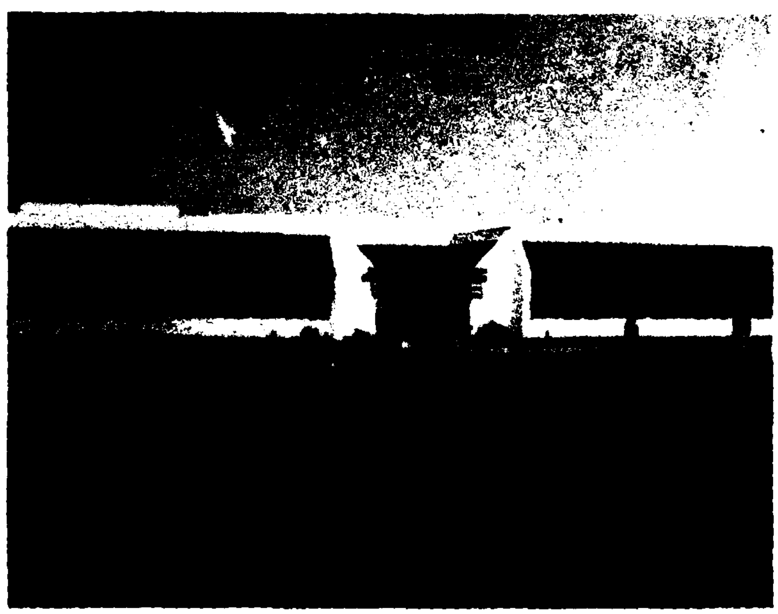
3627



3620

Enlisted Personnel Barracks Without Mess

3641



3641

Enlisted Personnel Mess

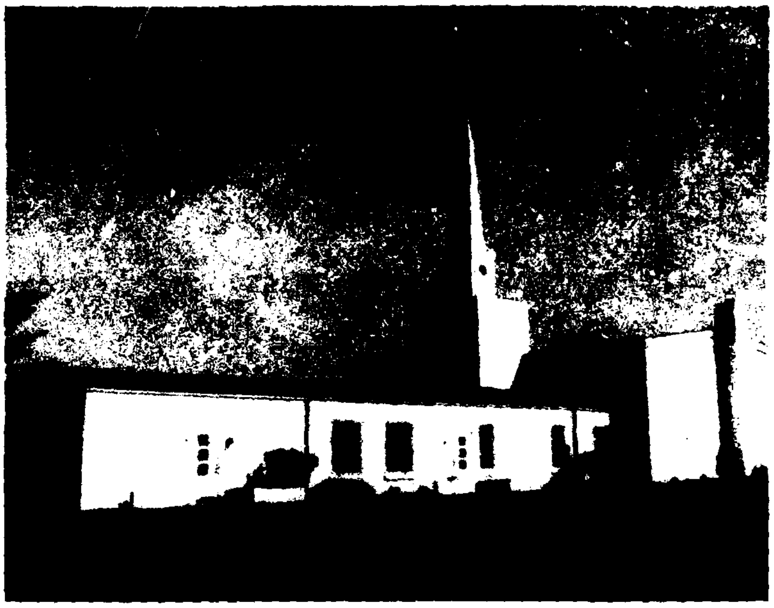
3641

3641

Enlisted Personnel Mess

3701

Unit Chapel



3701

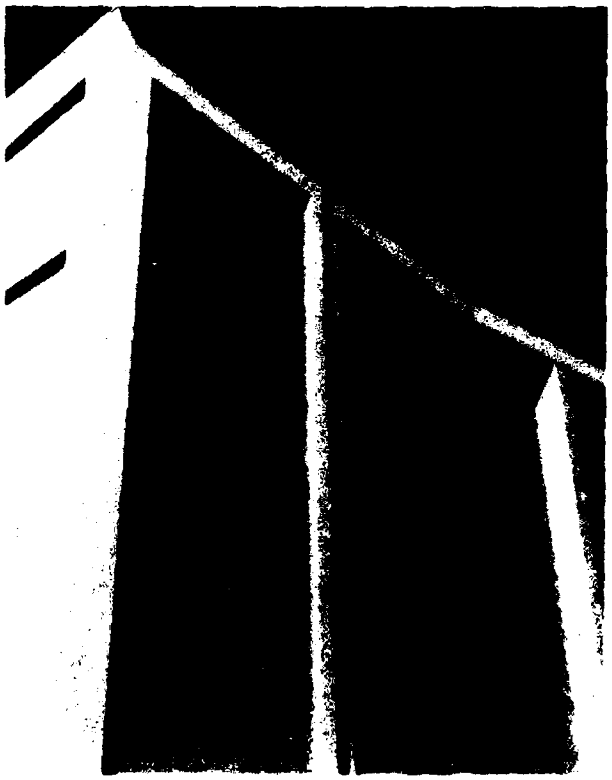
3701

Unit Chapel

3702

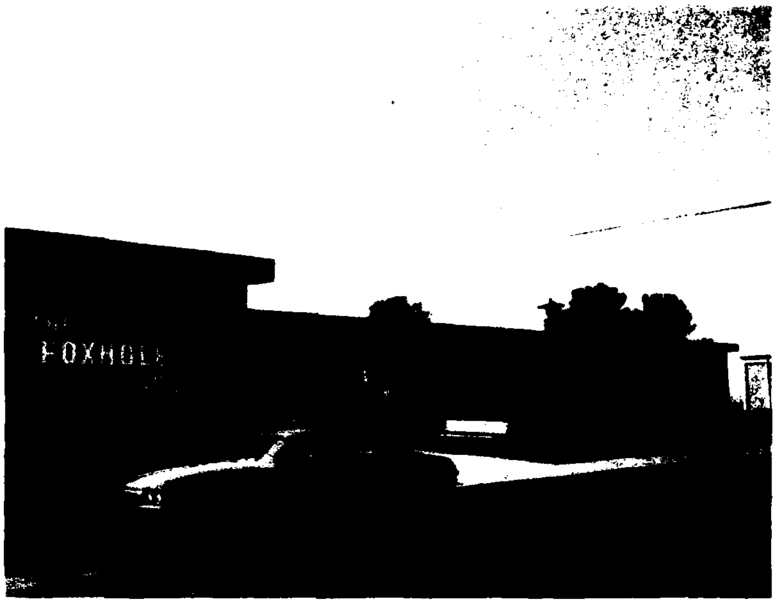
Theater Without Stage

3702

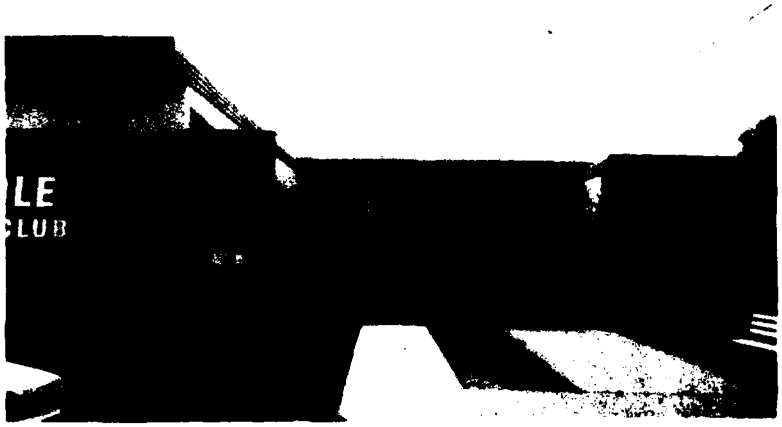


3702

Theater Without Stage



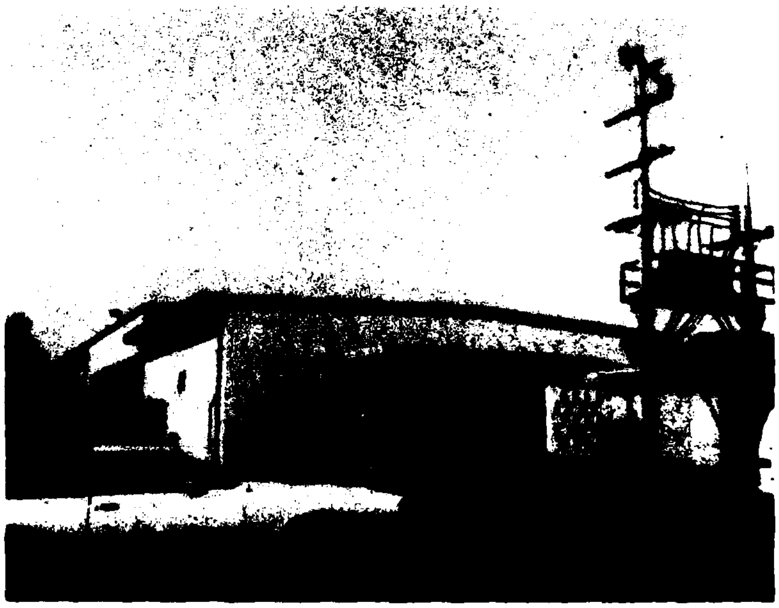
3703



3703

Enlisted Men's Service Club

3763



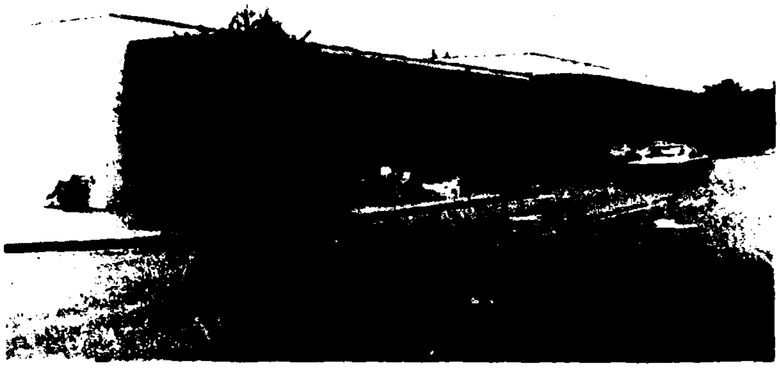
3703

Enlisted Men's Service Club

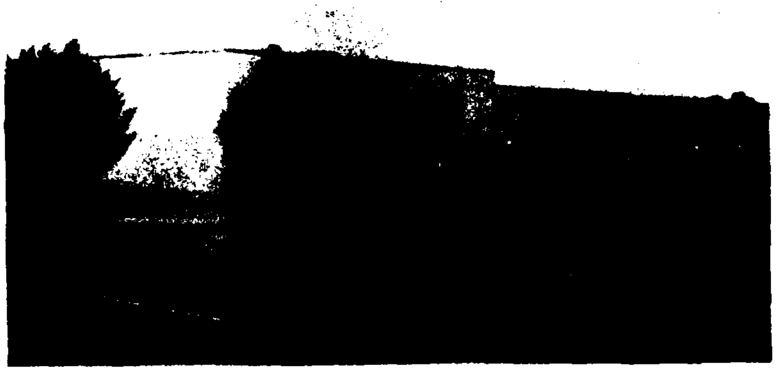
4200

4200

Fire Station

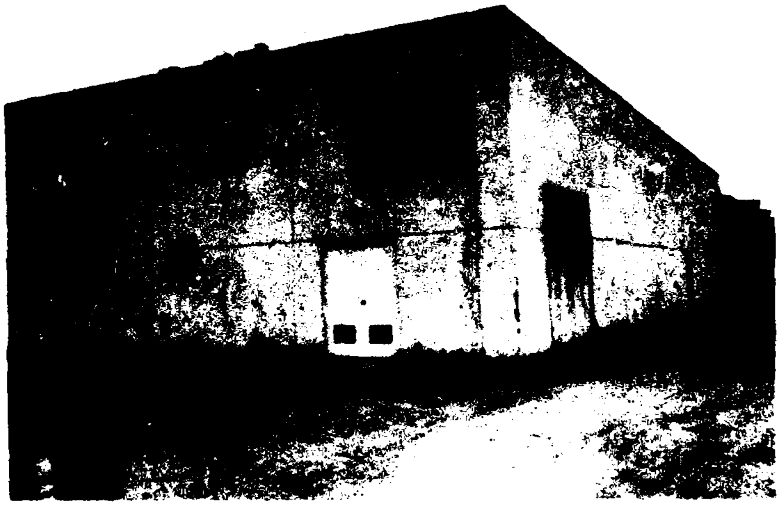


4235

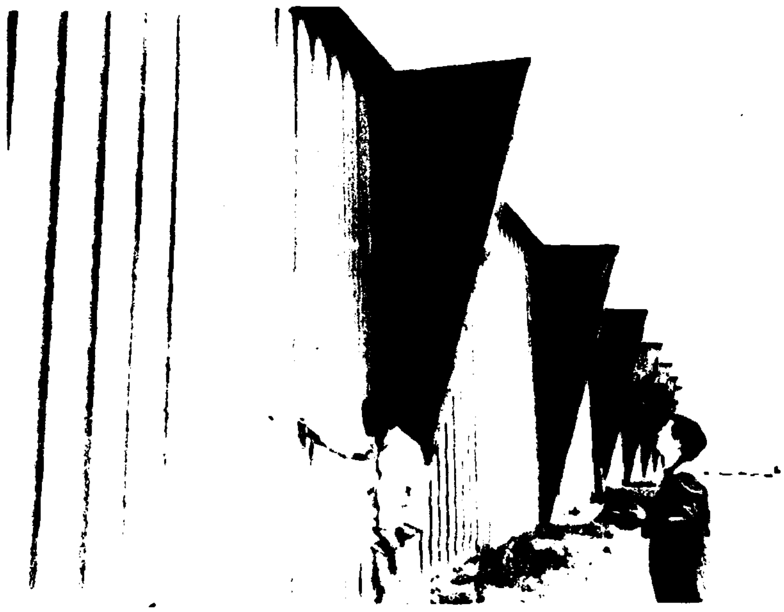


4235

Exchange, Main Retail Store

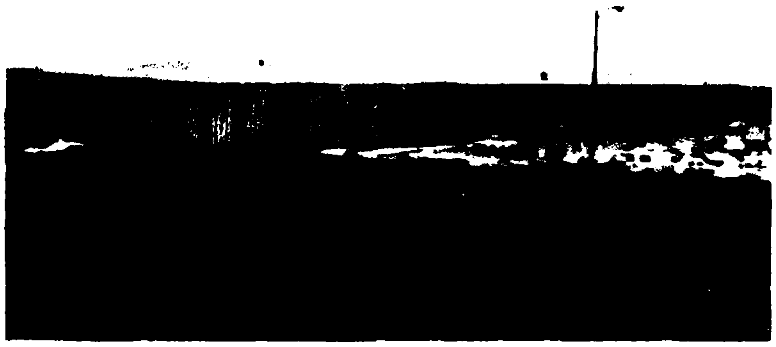


4235



4235

Exchange, Main Retail Store



4240

4240

Commissary

4240

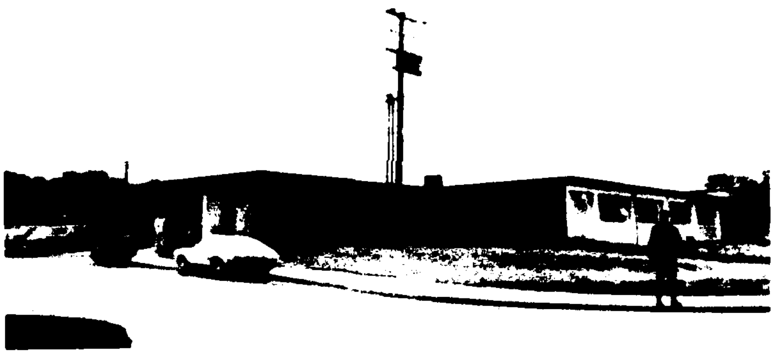
4240

Commissary

4250

4250

Telephone Exchange



4260

Open Mess, NCO

4280

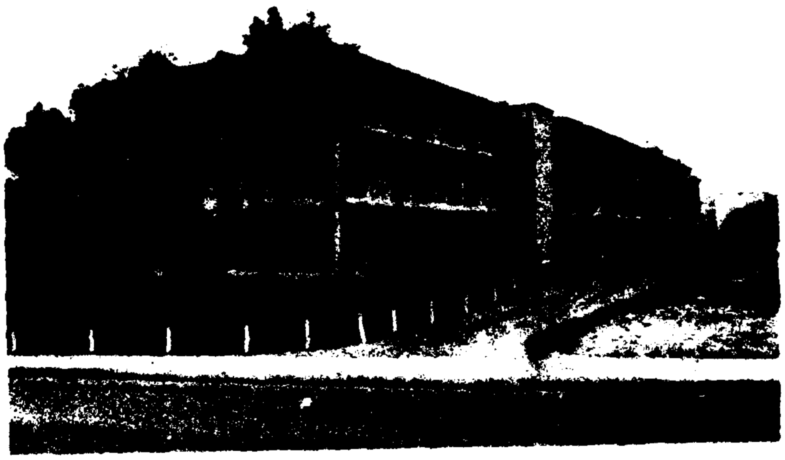
4280

Post Chapel

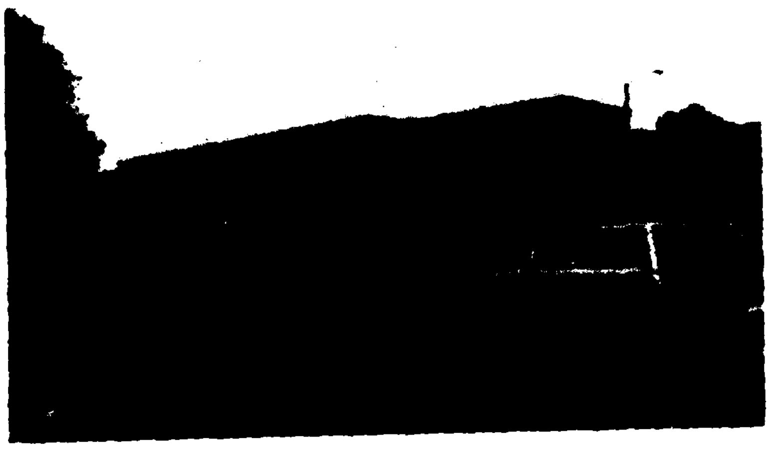
4280

4280

Post Chapel

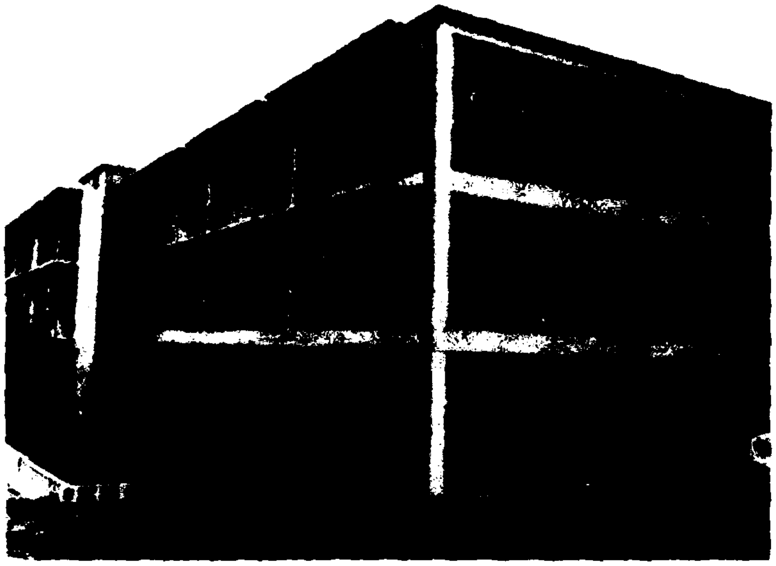


4471

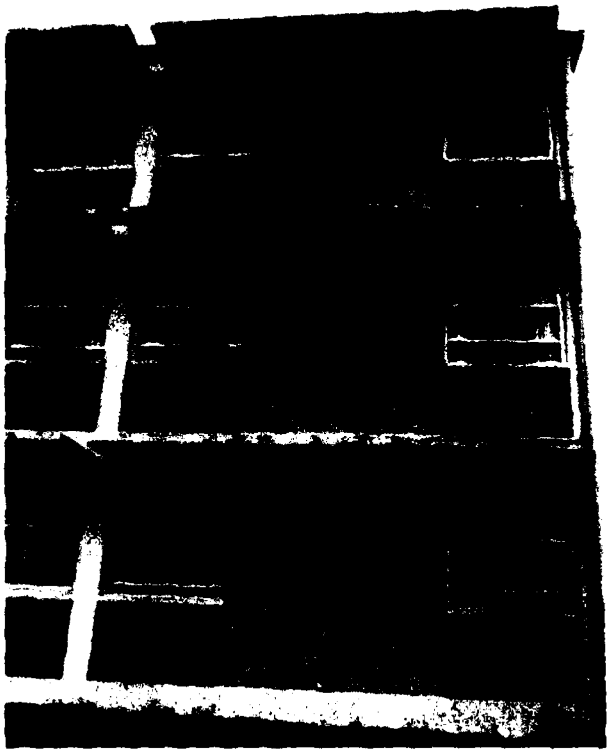


4471

Enlisted Personnel Barracks Without Mess

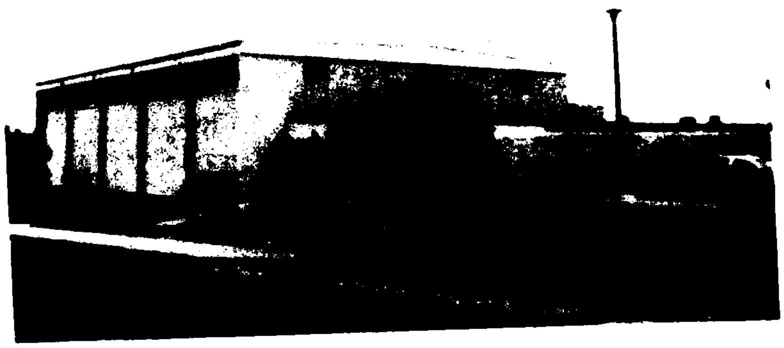


4471



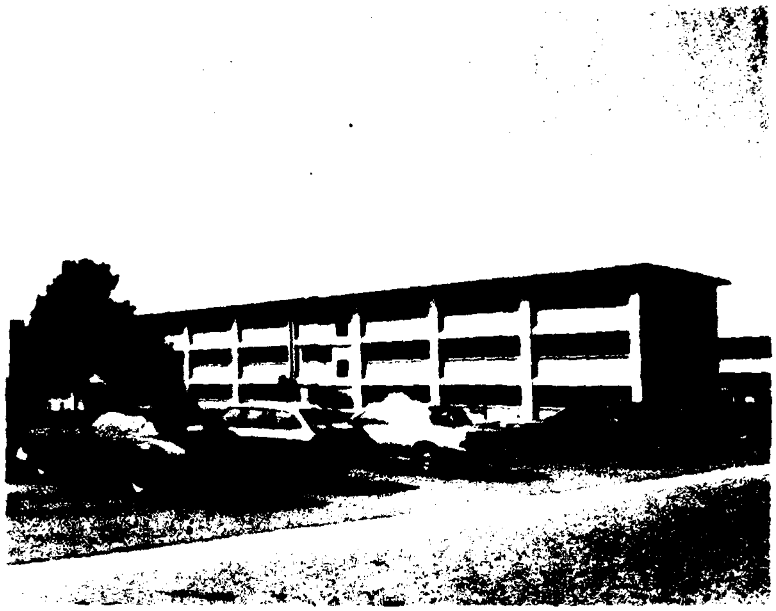
4471

Enlisted Personnel Barracks Without Mess

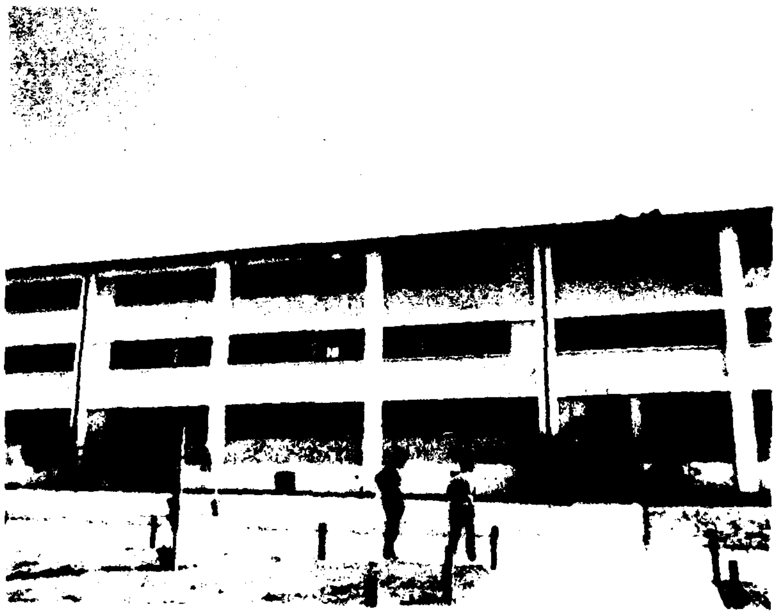


4480

Gymnasium



4782



4782

Enlisted Personnel Barracks With Mess

4784

4782

Enlisted Personnel Barracks With Mess

4953

Confinement Facility

4953

4953

Confinement Facility

APPENDIX B
COMPUTER OUTPUT OF EARTHQUAKE DAMAGE ESTIMATES

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

DIGITIZED SITE RESPONSE SPECTRA FOR .40 G

PERIOD	PERCENT OF CRITICAL DAMPING				
	0 PCNT	2 PCNT	5 PCNT	10 PCNT	20 PCNT
0.00	.40	.40	.40	.40	0.00
.03	.50	.40	.40	.40	0.00
.04	1.00	.40	.40	.40	0.00
.10	2.90	.90	.68	.51	0.00
.13	3.20	1.25	.77	.58	0.00
.17	3.90	1.43	.92	.65	0.00
.25	4.10	1.52	1.10	.76	0.00
.33	3.90	1.60	1.13	.80	0.00
.50	3.20	1.45	.95	.60	0.00
1.00	1.75	.95	.64	.45	0.00
1.25	1.45	.92	.54	.38	0.00
1.67	1.02	.80	.47	.32	0.00
2.50	.71	.51	.35	.24	0.00
3.33	.52	.37	.27	.19	0.00
5.00	.31	.22	.16	.12	0.00

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 507 FLIGHT MAINTENANCE AIRCRAFT HANGAR

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.140	.05	.410	.824	
ULTIMATE LEVEL	.230	.10	.610	.733	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.090	.05	.630	.633	
ULTIMATE LEVEL	.150	.10	.940	.622	1.000

BUILDING REPLACEMENT COST $ 2926000.

ESTIMATED TOTAL DAMAGE TO BUILDING 66.9 PERCENT

ESTIMATED COST OF DAMAGE $ 1958394.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.103	.092	0.0	.079	.078	0.0	0.0	0
.10	.206	.183	0.0	.158	.155	0.0	0.0	0
.15	.309	.275	0.0	.237	.233	0.0	0.0	0
.20	.412	.367	.7	.316	.311	0.0	.5	14
.25	.515	.458	40.9	.395	.389	0.0	27.2	797
.30	.618	.550	77.6	.474	.466	0.0	51.7	1514
.35	.721	.642	100.0	.553	.544	0.0	66.7	1950
.40	.824	.733	100.0	.633	.622	.8	66.9	1958
.45	.927	.825	100.0	.712	.699	25.3	75.1	2197
.50	1.029	.917	100.0	.791	.777	49.7	83.2	2434

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 2075 ENLISTED MEN'S SERVICE CLUB

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.090	.05	.827	.633	
ULTIMATE LEVEL	.120	.10	1.250	.377	1.500
LONGITUDINAL DIRECTION					
YIELD LEVEL	.060	.05	1.060	.490	
ULTIMATE LEVEL	.080	.10	1.620	.315	1.500

BUILDING REPLACEMENT COST $ 3649000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.079	.047	0.0	.061	.039	0.0	0.0	0
.10	.158	.094	0.0	.123	.079	0.0	0.0	0
.15	.237	.142	0.0	.184	.118	0.0	0.0	0
.20	.316	.189	0.0	.245	.158	0.0	0.0	0
.25	.395	.236	0.0	.306	.197	0.0	0.0	0
.30	.474	.283	0.0	.368	.236	0.0	0.0	0
.35	.553	.330	0.0	.429	.276	0.0	0.0	0
.40	.633	.377	0.0	.490	.315	0.0	0.0	0
.45	.712	.425	0.0	.551	.355	0.0	0.0	0
.50	.791	.472	0.0	.613	.394	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 3620 ENLISTED PERSONNEL BARRACKS W/O MESS

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.180	.05	.470	.948	
ULTIMATE LEVEL	.280	.10	.730	.775	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.190	.05	.430	.970	
ULTIMATE LEVEL	.290	.10	.650	.760	1.000

BUILDING REPLACEMENT COST $ 1332000.

ESTIMATED TOTAL DAMAGE TO BUILDING 100.0 PERCENT

ESTIMATED COST OF DAMAGE $ 1332000.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.119	.097	0.0	.121	.098	0.0	0.0	0
.10	.237	.194	0.0	.242	.195	0.0	0.0	0
.15	.356	.291	0.0	.364	.293	0.0	0.0	0
.20	.474	.388	1.2	.485	.390	17.4	12.0	160
.25	.593	.484	33.3	.606	.488	52.0	45.8	609
.30	.711	.581	61.8	.727	.585	82.1	75.3	1003
.35	.830	.678	87.4	.849	.683	100.0	95.8	1276
.40	.948	.775	100.0	.970	.780	100.0	100.0	1331
.45	1.067	.872	100.0	1.091	.877	100.0	100.0	1331
.50	1.185	.969	100.0	1.212	.975	100.0	100.0	1331

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 3641 ENLISTED PERSONNEL MESS

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.060	.05	1.070	.490	
ULTIMATE LEVEL	.090	.10	1.500	.491	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.060	.05	1.950	.490	
ULTIMATE LEVEL	.090	.10	2.730	.491	1.000

BUILDING REPLACEMENT COST $ 1614000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.061	.061	0.0	.061	.061	0.0	0.0	0
.10	.123	.123	0.0	.123	.123	0.0	0.0	0
.15	.184	.184	0.0	.184	.184	0.0	0.0	0
.20	.245	.246	0.0	.245	.246	0.0	0.0	0
.25	.306	.307	0.0	.306	.307	0.0	0.0	0
.30	.368	.369	0.0	.368	.369	0.0	0.0	0
.35	.429	.430	0.0	.429	.430	0.0	0.0	0
.40	.490	.491	0.0	.490	.491	0.0	0.0	0
.45	.551	.553	0.0	.551	.553	0.0	0.0	0
.50	.613	.614	0.0	.613	.614	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 3701 UNIT CHAPEL

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.130	.05	.940	.788	
ULTIMATE LEVEL	.140	.10	1.410	.605	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.090	.05	1.110	.633	
ULTIMATE LEVEL	.100	.10	1.670	.510	1.000

BUILDING REPLACEMENT COST $ 753000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.098	.076	0.0	.079	.064	0.0	0.0	0
.10	.197	.151	0.0	.158	.128	0.0	0.0	0
.15	.295	.227	0.0	.237	.191	0.0	0.0	0
.20	.394	.303	0.0	.316	.255	0.0	0.0	0
.25	.492	.378	0.0	.395	.319	0.0	0.0	0
.30	.591	.454	0.0	.474	.383	0.0	0.0	0
.35	.689	.529	0.0	.553	.446	0.0	0.0	0
.40	.788	.605	0.0	.633	.510	0.0	0.0	0
.45	.886	.681	0.0	.712	.574	0.0	0.0	0
.50	.985	.756	6.4	.791	.638	0.0	4.3	32

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 3702 THEATER W/O STAGE

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.100	.05	.670	.680	
ULTIMATE LEVEL	.110	.10	1.760	.538	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.080	.05	.770	.585	
ULTIMATE LEVEL	.090	.10	1.920	.491	1.000

BUILDING REPLACEMENT COST $ 1325000.

ESTIMATED TOTAL DAMAGE TO BUILDING .5 PERCENT

ESTIMATED COST OF DAMAGE $ 7170.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
	SPECTRAL ACCEL			SPECTRAL ACCEL				
MAX GRND ACCL. G	YIELD G	ULT. G	DAMAGE PCNT	YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.085	.067	0.0	.073	.061	0.0	0.0	0
.10	.170	.135	0.0	.146	.123	0.0	0.0	0
.15	.255	.202	0.0	.219	.184	0.0	0.0	0
.20	.340	.269	0.0	.293	.246	0.0	0.0	0
.25	.425	.336	0.0	.366	.307	0.0	0.0	0
.30	.510	.404	0.0	.439	.369	0.0	0.0	0
.35	.595	.471	0.0	.512	.430	0.0	0.0	0
.40	.680	.538	.8	.585	.491	0.0	.5	7
.45	.765	.605	7.6	.658	.553	0.0	5.1	67
.50	.850	.673	14.2	.731	.614	0.0	9.5	125

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 3703 ENLISTED MEN'S SERVICE CLUB

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.070	.05	1.070	.538	
ULTIMATE LEVEL	.100	.10	1.500	.510	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.060	.05	1.820	.490	
ULTIMATE LEVEL	.090	.10	2.550	.491	1.000

BUILDING REPLACEMENT COST $ 2252000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.067	.064	0.0	.061	.061	0.0	0.0	0
.10	.134	.128	0.0	.123	.123	0.0	0.0	0
.15	.202	.191	0.0	.184	.184	0.0	0.0	0
.20	.269	.255	0.0	.245	.246	0.0	0.0	0
.25	.336	.319	0.0	.306	.307	0.0	0.0	0
.30	.403	.383	0.0	.368	.369	0.0	0.0	0
.35	.470	.446	0.0	.429	.430	0.0	0.0	0
.40	.538	.510	0.0	.490	.491	0.0	0.0	0
.45	.605	.574	0.0	.551	.553	0.0	0.0	0
.50	.672	.638	0.0	.613	.614	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4200 FIRE STATION

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.080	.05	1.170	.585	
ULTIMATE LEVEL	.120	.10	1.760	.566	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.060	.05	1.070	.490	
ULTIMATE LEVEL	.100	.10	1.600	.510	1.000

BUILDING REPLACEMENT COST $ 468000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.073	.071	0.0	.061	.064	0.0	0.0	0
.10	.146	.142	0.0	.123	.128	0.0	0.0	0
.15	.219	.212	0.0	.184	.191	0.0	0.0	0
.20	.293	.283	0.0	.245	.255	0.0	0.0	0
.25	.366	.354	0.0	.306	.319	0.0	0.0	0
.30	.439	.425	0.0	.368	.383	0.0	0.0	0
.35	.512	.495	0.0	.429	.446	0.0	0.0	0
.40	.585	.566	0.0	.490	.510	0.0	0.0	0
.45	.658	.637	0.0	.551	.574	0.0	0.0	0
.50	.731	.708	0.0	.613	.638	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4235 EXCHANGE, MAIN RETAIL STORE

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	1.210	.05	.130	.556	
ULTIMATE LEVEL	2.220	.10	.200	.053	5.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.290	.05	.110	1.115	
ULTIMATE LEVEL	.530	.10	.170	.118	5.000

BUILDING REPLACEMENT COST $ 4617000.

ESTIMATED TOTAL DAMAGE TO BUILDING 88.2 PERCENT

ESTIMATED COST OF DAMAGE $ 4072102.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.070	.007	0.0	.139	.015	15.9	10.6	489
.10	.139	.013	4.6	.279	.030	54.6	37.9	1750
.15	.209	.020	30.4	.418	.044	71.0	57.5	2653
.20	.278	.027	46.1	.558	.059	80.1	68.8	3175
.25	.348	.033	56.6	.697	.074	85.9	76.2	3516
.30	.417	.040	64.2	.836	.089	89.9	81.4	3756
.35	.487	.047	69.9	.976	.103	92.9	85.2	3934
.40	.556	.053	74.4	1.115	.118	95.1	88.2	4072
.45	.626	.060	78.0	1.254	.133	96.9	90.6	4181
.50	.695	.067	80.9	1.394	.148	98.3	92.5	4270

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4240 COMMISSARY

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.100	.05	.610	.680	
ULTIMATE LEVEL	.160	.10	.940	.638	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.080	.05	.590	.585	
ULTIMATE LEVEL	.120	.10	.920	.566	1.000

BUILDING REPLACEMENT COST $ 4309000.

ESTIMATED TOTAL DAMAGE TO BUILDING 12.6 PERCENT

ESTIMATED COST OF DAMAGE $ 541040.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.085	.080	0.0	.073	.071	0.0	0.0	0
.10	.170	.160	0.0	.146	.142	0.0	0.0	0
.15	.255	.239	0.0	.219	.212	0.0	0.0	0
.20	.340	.319	0.0	.293	.283	0.0	0.0	0
.25	.425	.399	0.0	.366	.354	0.0	0.0	0
.30	.510	.479	0.0	.439	.425	0.0	0.0	0
.35	.595	.559	0.0	.512	.495	0.0	0.0	0
.40	.680	.638	18.8	.585	.566	0.0	12.6	541
.45	.765	.718	41.1	.658	.637	19.4	33.9	1460
.50	.850	.798	62.8	.731	.708	39.9	55.2	2378

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4250 TELEPHONE EXCHANGE

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.100	.05	.400	.680	
ULTIMATE LEVEL	.150	.10	.600	.622	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.050	.05	.710	.443	
ULTIMATE LEVEL	.080	.10	1.070	.473	1.000

BUILDING REPLACEMENT COST $ 1140000.

ESTIMATED TOTAL DAMAGE TO BUILDING 66.7 PERCENT

ESTIMATED COST OF DAMAGE $ 760000.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.085	.078	0.0	.055	.059	0.0	0.0	0
.10	.170	.155	0.0	.111	.118	0.0	0.0	0
.15	.255	.233	0.0	.166	.177	0.0	0.0	0
.20	.340	.311	0.0	.221	.236	0.0	0.0	0
.25	.425	.389	10.6	.277	.295	0.0	7.0	80
.30	.510	.466	45.1	.332	.355	0.0	30.1	342
.35	.595	.544	77.7	.387	.414	0.0	51.8	590
.40	.680	.622	100.0	.443	.473	0.0	66.7	759
.45	.765	.699	100.0	.498	.532	0.0	66.7	759
.50	.850	.777	100.0	.553	.591	0.0	66.7	759

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4260 OPEN MESS NCO

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.030	.05	1.130	.400	
ULTIMATE LEVEL	.031	.10	2.920	.400	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.030	.05	1.000	.400	
ULTIMATE LEVEL	.032	.10	2.730	.400	1.000

BUILDING REPLACEMENT COST $ 2670000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE ESI 1000 $
.05	.050	.050	0.0	.050	.050	0.0	0.0	0
.10	.100	.100	0.0	.100	.100	0.0	0.0	0
.15	.150	.150	0.0	.150	.150	0.0	0.0	0
.20	.200	.200	0.0	.200	.200	0.0	0.0	0
.25	.250	.250	0.0	.250	.250	0.0	0.0	0
.30	.300	.300	0.0	.300	.300	0.0	0.0	0
.35	.350	.350	0.0	.350	.350	0.0	0.0	0
.40	.400	.400	0.0	.400	.400	0.0	0.0	0
.45	.450	.450	0.0	.450	.450	0.0	0.0	0
.50	.500	.500	0.0	.500	.500	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4280A POST CHAPEL, CHAPEL WING

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.180	.05	1.010	.948	
ULTIMATE LEVEL	.260	.10	1.420	.765	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.110	.05	1.540	.716	
ULTIMATE LEVEL	.160	.10	2.150	.638	1.000

BUILDING REPLACEMENT COST $ 782000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	TRANSVERSE ULT. G	TRANSVERSE DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	LONGITUDINAL ULT. G	LONGITUDINAL DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.119	.096	0.0	.090	.080	0.0	0.0	0
.10	.237	.191	0.0	.179	.160	0.0	0.0	0
.15	.356	.287	0.0	.269	.239	0.0	0.0	0
.20	.474	.383	0.0	.358	.319	0.0	0.0	0
.25	.593	.478	0.0	.448	.399	0.0	0.0	0
.30	.711	.574	0.0	.537	.479	0.0	0.0	0
.35	.830	.669	0.0	.627	.559	0.0	0.0	0
.40	.948	.765	0.0	.716	.638	0.0	0.0	0
.45	1.067	.861	9.2	.806	.718	0.0	6.1	47
.50	1.185	.956	27.4	.895	.798	0.0	18.3	142

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4280B POST CHAPEL, CENTRAL WING

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.060	.05	.890	.490	
ULTIMATE LEVEL	.090	.10	1.230	.491	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.040	.05	1.460	.400	
ULTIMATE LEVEL	.060	.10	2.040	.435	1.000

BUILDING REPLACEMENT COST $ 835000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.061	.061	0.0	.050	.054	0.0	0.0	0
.10	.123	.123	0.0	.100	.109	0.0	0.0	0
.15	.184	.184	0.0	.150	.163	0.0	0.0	0
.20	.245	.246	0.0	.200	.218	0.0	0.0	0
.25	.306	.307	0.0	.250	.272	0.0	0.0	0
.30	.368	.369	0.0	.300	.327	0.0	0.0	0
.35	.429	.430	0.0	.350	.381	0.0	0.0	0
.40	.490	.491	0.0	.400	.435	0.0	0.0	0
.45	.551	.553	0.0	.450	.490	0.0	0.0	0
.50	.613	.614	0.0	.500	.544	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4280C POST CHAPEL, CLASS ROOMS

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.050	.05	1.710	.443	
ULTIMATE LEVEL	.090	.10	2.400	.491	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.050	.05	1.710	.443	
ULTIMATE LEVEL	.090	.10	2.400	.491	1.000

BUILDING REPLACEMENT COST $ 592000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.055	.061	0.0	.055	.061	0.0	0.0	0
.10	.111	.123	0.0	.111	.123	0.0	0.0	0
.15	.166	.184	0.0	.166	.184	0.0	0.0	0
.20	.221	.246	0.0	.221	.246	0.0	0.0	0
.25	.277	.307	0.0	.277	.307	0.0	0.0	0
.30	.332	.369	0.0	.332	.369	0.0	0.0	0
.35	.387	.430	0.0	.387	.430	0.0	0.0	0
.40	.443	.491	0.0	.443	.491	0.0	0.0	0
.45	.498	.553	0.0	.498	.553	0.0	0.0	0
.50	.553	.614	0.0	.553	.614	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4471 ENLISTED PERSONNEL BARRACK W/O MESS

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.140	.05	.170	.824	
ULTIMATE LEVEL	.160	.10	.410	.638	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.060	.05	.380	.490	
ULTIMATE LEVEL	.080	.10	.640	.473	1.000

BUILDING REPLACEMENT COST $ 2409000.

ESTIMATED TOTAL DAMAGE TO BUILDING 79.9 PERCENT

ESTIMATED COST OF DAMAGE $ 1924845.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
	SPECTRAL ACCEL			SPECTRAL ACCEL				
MAX GRND ACCL. G	YIELD G	ULT. G	DAMAGE PCNT	YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.103	.080	0.0	.061	.059	0.0	0.0	0
.10	.206	.160	12.5	.123	.118	0.0	8.4	201
.15	.309	.239	44.9	.184	.177	0.0	29.9	720
.20	.412	.319	72.7	.245	.236	0.0	48.5	1167
.25	.515	.399	96.9	.306	.295	0.0	64.6	1556
.30	.618	.479	100.0	.368	.355	0.0	66.7	1605
.35	.721	.559	100.0	.429	.414	17.8	72.6	1748
.40	.824	.638	100.0	.490	.473	39.7	79.9	1924
.45	.927	.718	100.0	.551	.532	61.3	87.1	2098
.50	1.029	.798	100.0	.613	.591	82.6	94.2	2269

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4480 GYMNASIUM

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.110	.05	.890	.716	
ULTIMATE LEVEL	.160	.10	1.330	.638	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.090	.05	1.600	.633	
ULTIMATE LEVEL	.130	.10	2.400	.588	1.000

BUILDING REPLACEMENT COST $ 1677000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.090	.080	0.0	.079	.074	0.0	0.0	0
.10	.179	.160	0.0	.158	.147	0.0	0.0	0
.15	.269	.239	0.0	.237	.221	0.0	0.0	0
.20	.358	.319	0.0	.316	.294	0.0	0.0	0
.25	.448	.399	0.0	.395	.368	0.0	0.0	0
.30	.537	.479	0.0	.474	.441	0.0	0.0	0
.35	.627	.559	0.0	.553	.515	0.0	0.0	0
.40	.716	.638	0.0	.633	.588	0.0	0.0	0
.45	.806	.718	0.0	.712	.662	0.0	0.0	0
.50	.895	.798	.9	.791	.735	0.0	.6	10

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4782A ENLISTED PERSONNEL BARRACKS W/MESS, MESS

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA-STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.060	.05	.860	.490	
ULTIMATE LEVEL	.090	.10	1.330	.491	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.040	.05	1.050	.400	
ULTIMATE LEVEL	.060	.10	1.610	.435	1.000

BUILDING REPLACEMENT COST $ 352000.

ESTIMATED TOTAL DAMAGE TO BUILDING 0.0 PERCENT

ESTIMATED COST OF DAMAGE $ 0.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
MAX GRND ACCL. G	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	SPECTRAL ACCEL YIELD G	SPECTRAL ACCEL ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.061	.061	0.0	.050	.054	0.0	0.0	0
.10	.123	.123	0.0	.100	.109	0.0	0.0	0
.15	.184	.184	0.0	.150	.163	0.0	0.0	0
.20	.245	.246	0.0	.200	.218	0.0	0.0	0
.25	.306	.307	0.0	.250	.272	0.0	0.0	0
.30	.368	.369	0.0	.300	.327	0.0	0.0	0
.35	.429	.430	0.0	.350	.381	0.0	0.0	0
.40	.490	.491	0.0	.400	.435	0.0	0.0	0
.45	.551	.553	0.0	.450	.490	0.0	0.0	0
.50	.613	.614	0.0	.500	.544	0.0	0.0	0

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4782B ENLISTED PERSONNEL BARRACKS W/MESS, BARRACKS

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.140	.05	.270	.824	
ULTIMATE LEVEL	.190	.10	.490	.680	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.050	.05	.140	.443	
ULTIMATE LEVEL	.060	.10	.300	.435	1.000

BUILDING REPLACEMENT COST $ 2141000.

ESTIMATED TOTAL DAMAGE TO BUILDING 100.0 PERCENT

ESTIMATED COST OF DAMAGE $ 2141000.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

	TRANSVERSE DIRECTION			LONGITUDINAL DIRECTION				
	SPECTRAL ACCEL			SPECTRAL ACCEL				
MAX GRND ACCL. G	YIELD G	ULT. G	DAMAGE PCNT	YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.103	.085	0.0	.055	.054	0.0	0.0	0
.10	.206	.170	0.0	.111	.109	0.0	0.0	0
.15	.309	.255	14.2	.166	.163	16.0	15.4	329
.20	.412	.340	48.6	.221	.218	49.7	49.4	1056
.25	.515	.425	79.1	.277	.272	83.1	81.7	1750
.30	.618	.510	100.0	.332	.327	100.0	100.0	2140
.35	.721	.595	100.0	.387	.381	100.0	100.0	2140
.40	.824	.680	100.0	.443	.435	100.0	100.0	2140
.45	.927	.766	100.0	.498	.490	100.0	100.0	2140
.50	1.029	.851	100.0	.553	.544	100.0	100.0	2140

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF EARTHQUAKE

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

BLDG 4953 CONFINEMENT FACILITY

BUILDING PROPERTIES AND DAMAGE ESTIMATE FOR A NOMINAL ACCELERATION OF .40 G

	PERIOD (SEC)	DAMPING	SA STR CAPACITY (G)	SA SITE DEMAND (G)	R
TRANSVERSE DIRECTION					
YIELD LEVEL	.080	.05	.520	.585	
ULTIMATE LEVEL	.100	.10	1.090	.510	1.000
LONGITUDINAL DIRECTION					
YIELD LEVEL	.060	.05	.830	.490	
ULTIMATE LEVEL	.080	.10	1.570	.473	1.000

BUILDING REPLACEMENT COST $ 4070000.

ESTIMATED TOTAL DAMAGE TO BUILDING 6.7 PERCENT

ESTIMATED COST OF DAMAGE $ 273757.

DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS

MAX GRND ACCL. G	TRANSVERSE DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	LONGITUDINAL DIRECTION SPECTRAL ACCEL YIELD G	ULT. G	DAMAGE PCNT	COMBINED DAMAGE PCNT	DAMAGE EST 1000 $
.05	.073	.064	0.0	.061	.059	0.0	0.0	0
.10	.146	.128	0.0	.123	.118	0.0	0.0	0
.15	.219	.191	0.0	.184	.177	0.0	0.0	0
.20	.293	.255	0.0	.245	.236	0.0	0.0	0
.25	.366	.319	0.0	.306	.295	0.0	0.0	0
.30	.439	.383	0.0	.368	.355	0.0	0.0	0
.35	.512	.446	0.0	.429	.414	0.0	0.0	0
.40	.585	.510	10.1	.490	.473	0.0	6.7	273
.45	.658	.574	21.1	.551	.532	0.0	14.1	573
.50	.731	.638	31.8	.613	.591	0.0	21.2	863

SUMMARY OF DAMAGE ESTIMATES FOR VARIOUS LEVELS OF MAXIMUM GROUND ACCELERATIONS IN G'S

VALUES ARE GIVEN IN THOUSANDS OF DOLLARS

DAMAGE ESTIMATE FOR SELECTED BUILDINGS AT FORT ORD, CALIFORNIA 11-23-81

	.05G	.10G	.15G	.20G	.25G	.30G	.35G	.40G	.45G	.50G	REPL COST
BLDG 507	0	0	0	14	797	1514	1950	1958	2197	2434	2926
BLDG 2075	0	0	0	0	0	0	0	0	0	0	3649
BLDG 3620	0	0	0	160	609	1003	1276	1331	1331	1331	1332
BLDG 3641	0	0	0	0	0	0	0	0	0	0	1614
BLDG 3701	0	0	0	0	0	0	0	0	0	32	753
BLDG 3702	0	0	0	0	0	0	0	7	67	125	1325
BLDG 3703	0	0	0	0	0	0	0	0	0	0	2252
BLDG 4200	0	0	0	0	0	0	0	0	0	0	468
BLDG 4235	489	1750	2653	3175	3516	3756	3934	4072	4181	4270	4617
BLDG 4240	0	0	0	0	0	0	0	541	1460	2378	4309
BLDG 4250	0	0	0	0	80	342	590	759	759	759	1140
BLDG 4260	0	0	0	0	0	0	0	0	0	0	2670
BLDG 4280A	0	0	0	0	0	0	0	0	47	142	782
BLDG 4280B	0	0	0	0	0	0	0	0	0	0	835
BLDG 4280C	0	0	0	0	0	0	0	0	0	0	592
BLDG 4471	0	201	720	1167	1556	1605	1748	1924	2098	2269	2409
BLDG 4480	0	0	0	0	0	0	0	0	0	10	1677
BLDG 4782A	0	0	0	0	0	0	0	0	0	0	352
BLDG 4782B	0	0	329	1056	1750	2140	2140	2140	2140	2140	2141
BLDG 4953	0	0	0	0	0	0	0	273	573	863	4070
TOTAL	489	1951	3702	5572	8308	10360	11638	13005	14853	16753	39913
PERCENT	1.2	4.9	9.3	14.0	20.8	26.0	29.2	32.6	37.2	42.0	

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